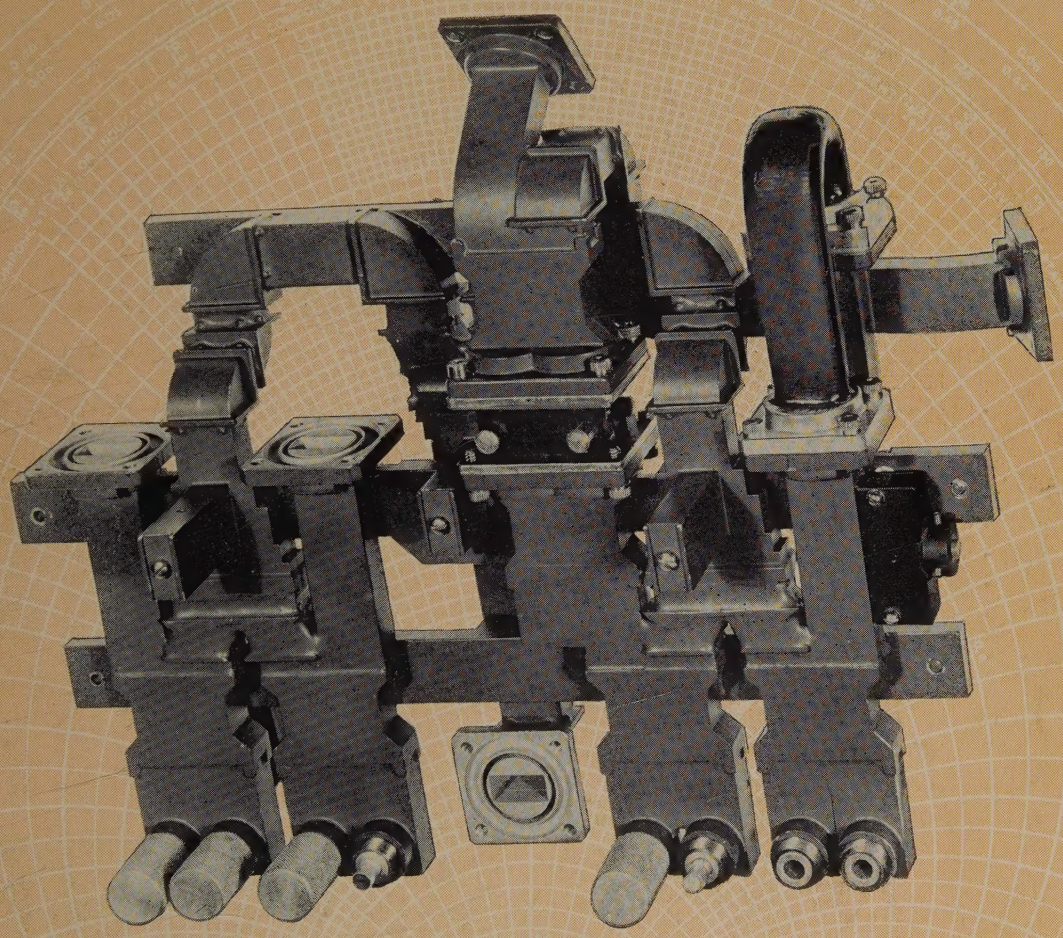
NOVEMBER 1959
VOL. 2 • NO. 11

- WHITWELL & WILLIAMS — A New Microwave Technique for Determining Noise Spectra at Frequencies Close to the Carrier.
- COHEN & STEINMETZ — Amplitude- and Phase-Sensing Monopulse System Parameters, Part II.
- HENSPERGER — A Simplified Approach to the Design of Bandpass Filters in Waveguide.

NOV 2 0 1959

the microwave journal

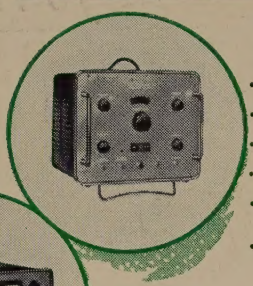


Robert H. Maier, Prin. Engr.
Kellogg Switchboard & Supply
6000 W. 51st St.
Chicago 38, Ill.

NEXT ISSUE — STATE OF ART OF HIGH POWER TWT'S — ANTENNA SHIELD AND TEST COUPLER — REFLEX KLYSTRON AMPLIFIER NOISE

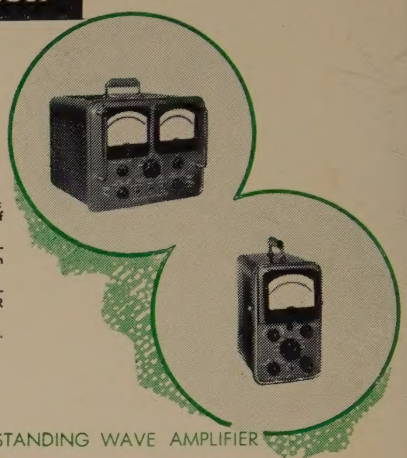
FXR's wide selection of microwave test equipment and waveguide components cover the frequency spectrum from 350 megacycles to 220 kilomegacycles—from the giant size WR-2100 components to the 2 MM & 3 MM wavelength miniature instruments. High power pulse modulators and high-voltage power supplies are equally prominent in FXR's production line.

MICROWAVE INSTRUMENTATION



SIGNAL SOURCES

- Model L771B: 950 to 2000 MC/SEC.
- Model S771B: 1900 to 4000 MC/SEC.
- Model C772A: 3950 to 8200 MC/SEC.
- Model X772A: 7000 to 11,000 MC/SEC.
- Power Output: 10-100 MW CW, MAX. into matched load. Variable through level-set attenuator.
- Modulation: pulse, square wave both internal and external.



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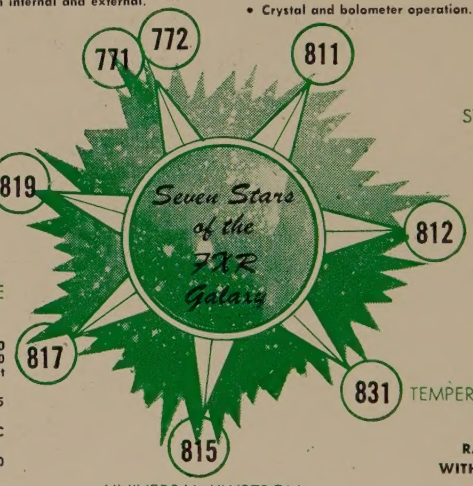
RATIO METER AND STANDING WAVE AMPLIFIER IN ONE COMPACT PACKAGE

- Two-cycle Precision Logmeter: VSWR reflectometer readings of 1.02 to ∞ on only two scales.
- VSWR, DB and reflection coefficient scales eliminate conversion tables.
- Full 70 DB standing wave amplifier operation, expanded VSWR scales.
- Crystal and bolometer operation.

KLYSTRON POWER SUPPLY

- Beam: 300-1000 V at 85 MA.
- Grid: −300 to +150 V at 0 to 5 MA. Built-in limiting resistor.
- Reflector: 0-900 V at 10-20 μA.
- Regulation: 1%.
- Internal Modulation: pulse, sawtooth, square wave.



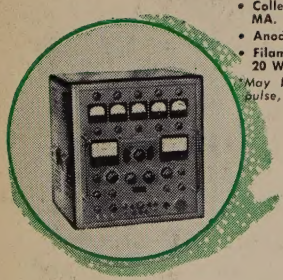
STANDING WAVE AMPLIFIER

- A 5-inch removable meter with 1% linearity provides high resolution and accuracy.
- A filter, tunable between 950 and 1050 CPS, aligns instrument with output frequency of signal source.
- Range: 70 DB in six decade steps. Normal and expanded scales for VSWR and DB.
- Gain automatically maintained when switching from normal to expanded scales.
- Detectors: crystal or bolometer.
- Full scale sensitivity, 0.1 μV: signal-to-noise ratio, 3:1.

UNIVERSAL MICROWAVE POWER SUPPLY

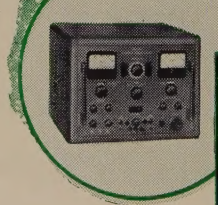
- Helix (beam): 0 to 1800 V at 0 to 100 MA; 1700 to 2500 V at 0 to 100 MA; 2500 to 3500 V at 250 W MAX.
- *Grid 1: 0-300 V DC at 0 to 5 MA.
- *Grid 2 (reflector): 0-1200 V DC at 0 to 1 MA.
- *Grid 3 (focusing electrode): 0 to 750 V DC at 0-1 MA.
- *Grid 4 (focusing electrode): 0 to 500 V DC at 0-1 MA.
- Collector: 0-300 V DC at 0-100 MA.
- Anode: 0-600 V DC at 0-0.60 MA.
- Filament: 0-15 V DC, 0-3 AMP at 20 W MAX.

*May be internally modulated: pulse, sawtooth, square wave.



UNIVERSAL KLYSTRON POWER SUPPLY

- Beam: 200 to 2000 V at 0 to 125 MA, 1800 to 3600 V, 250 W to 3600 V.
- Control Grid: Pos. 0 to 150 V, Neg. 0 to 300 V.
- Reflector: 0 to 1000 V.
- Regulation: 0.03%.
- Ripple: 3 MV, RMS, MAX.
- Internal Modulation: pulse, sawtooth, square wave.



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FIRST commercially available DC comparison radiometer — 1953

FIRST commercially available 50 kw CW power amplifiers at 960 Mc — 1955

FIRST typewritten display of extraterrestrial radio radiation — 1956

FIRST radiometer with a sensitivity of 1/400,000 — 1956

FIRST radio detection of planetary nebulae — 1957

FIRST radio detection of planet Saturn — 1957

FIRST commercially available gain-modulated switched load radiometers — 1959

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Ewen Knight CORPORATION

AT THE FRONTIERS OF Electronics

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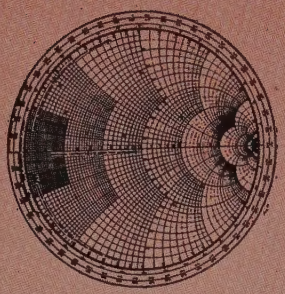

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OUR COVER

A monopulse RF mixer assembly which includes three balanced crystal mixers for the monopulse signals and one mixer for AFC purposes. Duplexing is achieved with two short slot hybrids and a dual TR tube. See page 33.

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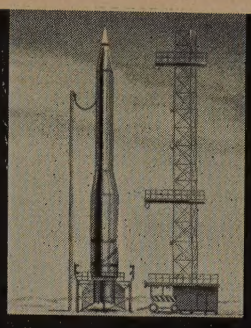

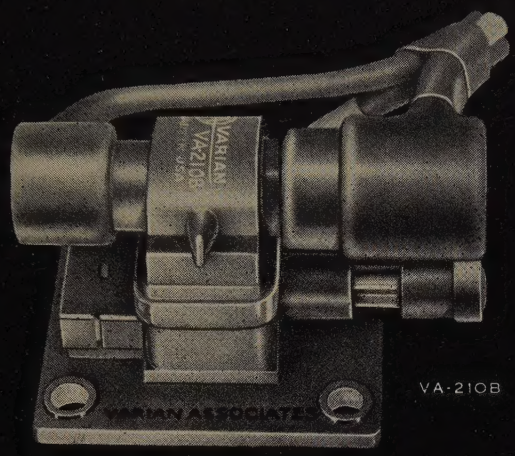

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The new VA-210B Klystron is a super-rugged oscillator, engineered to give long, reliable service under severe operating conditions. Frequency is extremely stable, even under conditions of the most severe shock, vibration and temperature variation. Features include a unique brazed-on external tuning cavity, a very rugged, quick-heating cathode, a slow-rate non-microphonic tuner and an all metal and ceramic construction.

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VA-203B

VA-221H

VA-94

VA-210B . . .	9.6 to 10.8 kMc . . .	30 mW
VA-201B . . .	8.5 to 9.6 kMc	90 mW
VA-203B . . .	8.5 to 9.6 kMc	30 mW
VA-94	16.0 to 17.0 kMc . . .	40 mW
VA-221H . . .	5.25 to 5.56 kMc . . .	40 mW

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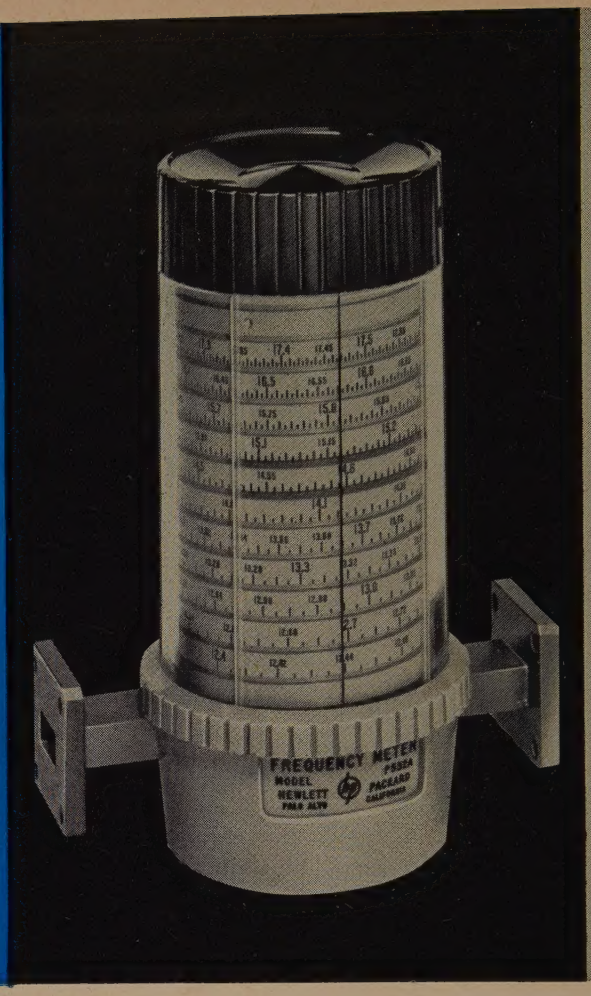

NEW K AND R BAND MODELS

Now hp offers you high quality, moderately-priced precision Frequency Meters covering the important J, H, X, P, K and R microwave bands.

On models 532A (X through R band) frequency is read directly in KMC on the large, precisely-calibrated spiral scale. No charts or interpolation are required. Accuracy is high, typically 0.1%.

Model 532A Frequency Meters comprise a special waveguide section mounting a high Q resonant cavity tuned by a choke plunger. No sliding contacts are used, and the waveguide section transmits virtually full power at resonance. A dip in output indicates resonance. Tuning is by a precision lead screw, spring loaded to eliminate backlash. Scale lengths of 77" calibrated in 5 MC increments are typical.

For J and H band work (5.20 to 10.0 KMC) Model 530 Frequency Meters are offered (see Table). These instruments are similar to Model 532A except tuning is by a micrometer, and readings are converted to frequency by a chart on the instrument.

SPECIFICATIONS

Model	Accuracy	Frequency Range KMC	Fits Waveguide Size (in.)	Length (in.)	Price
J530A	0.1%	5.85 - 8.20	1½ x ¾	4	$120.00
J530B	0.1%	5.20 - 7.05	1½ x ¾	4	150.00
H530A	0.1%	7.05 - 10.0	1¼ x ⅝	3½	120.00
X532A	0.08%	8.20 - 12.4	1 x ½	4½	150.00
P532A	0.1%	12.4 - 18.0	.702 x .391	4½	210.00
K532A	0.1%	18.0 - 26.5	½ x ¼	4½	230.00
R532A	0.2%	26.5 - 40.0	.360 x .220	4½	250.00

Other specifications: Models 532A: Resetability 0.01%, backlash 0.005%, SWR at resonance 1.3:1 approximately. Dip at resonance, 1 db or more.

For complete details, call your hp representative or write direct.

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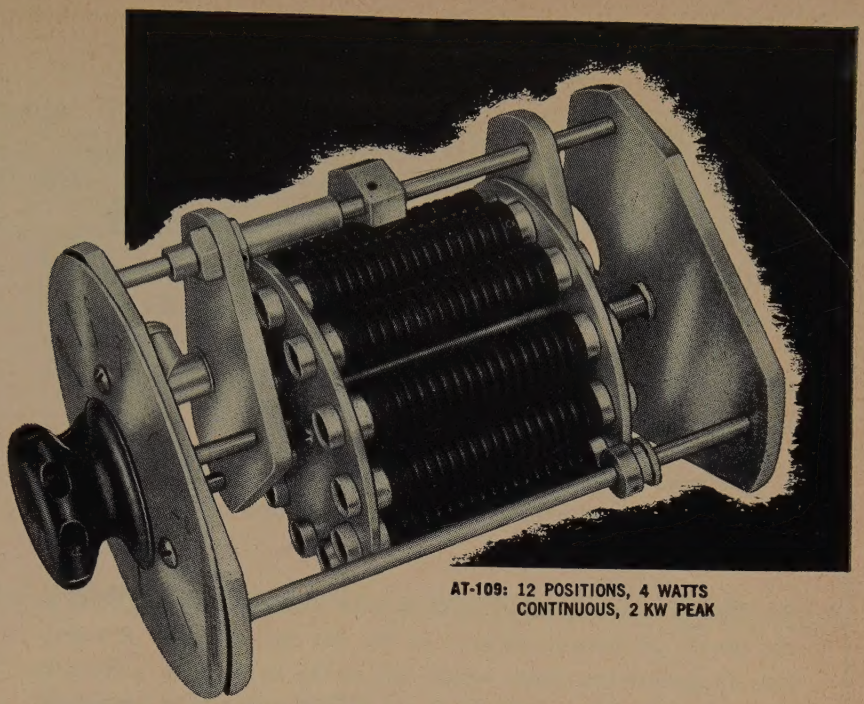


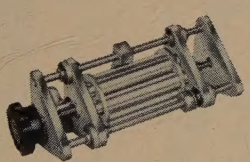
AT-109: 12 POSITIONS, 4 WATTS CONTINUOUS, 2 KW PEAK

EMPIRE
COAXIAL ATTENUATORS

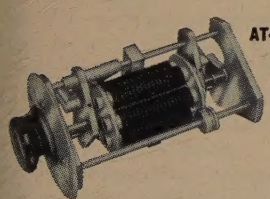
AT-50: 1 W CONT., 1 KW PEAK
AT-60: 2 W CONT., 2 KW PEAK

AT-75: 4 W CONT., 2 KW PEAK

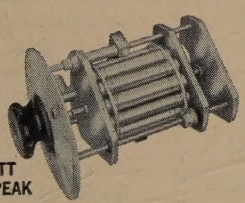
AT-106: ATTENUATOR PANEL FOR VALUES UP TO 120 DB USING COMBINATIONS OF STEP ATTENUATORS.



AT-103: 6 POSITIONS, 1 WATT CONTINUOUS, 1 KW PEAK



AT-108: 6 POSITIONS, 4 WATT CONTINUOUS, 2 KW PEAK



AT-104: 12 POSITIONS, 1 WATT CONTINUOUS, 1 KW PEAK

Rated up to 4 Watts

Empire attenuators have been designed and constructed for the reliable performance so essential to modern, complex systems. Their rugged construction ...conservative power ratings for CW and pulse operation...and exclusive deposited carbon precision resistors...enable them to satisfy your microwave attenuation requirements.

Resistive coaxial networks furnished for frequencies up to 4000 MC, higher on special order. Low VSWR and high accuracy are inherent features. Attenuation values up to 60 DB are obtained in individual pads, rated up to 4 watts continuous and 2 KW peak (AT-75) or as six and twelve position step attenuators (AT-108, AT-109). With two or three attenuators connected in series, values up to 120 DB can be obtained.

In many cases our engineering files contain a ready solution to your unusual coaxial attenuation problems.

For complete technical information, write for free catalog A-259.

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THE EDITOR VIEWS . . .

The growing thaw in the cold war is a matter that concerns all mankind. The talks between our Government and the Russian Government appear to be achieving some small measure of success. In some areas the long forgotten hopes for a lasting peace are beginning to stir ever so slightly.

We must try not to let our special situation color our opinions of the present negotiations. The effort required to be completely objective is a large one.

The microwave industry owes most of its phenomenal growth to the liberal government support of the last two decades. A reduction of government funds would reduce the industry to a fraction of its present size — certainly in the initial stages of a prolonged peace. The microwave industry has had very little opportunity to test itself under conditions of a truly peace time economy.

With these thoughts in mind, it might be well to consider some of the attitudes prevalent in our society regarding the present world situation.

There are people who believe that lasting peace will be achieved only if the world is an armed camp with adversaries equally balanced. This group believes that human frailties are, in general, incurable and take what they believe is a realistic position.

There are other people who feel that only through complete disarmament by all countries can we achieve the conditions necessary to a true and lasting peace.

Still another group is in favor of present world tensions because of the stimulus it has on the economy. These people are not interested in the future effects, but concern themselves only with present gains.

There are an infinite variety of opinions that prevail regarding the present situation. The three groups listed above are only typical of a few.

People in the microwave industry are faced with some very serious problems. One is the danger that some of us may be classed in the third group above when our true opinions are identical to those of the first group.

Ted Saad

LETTERS

Mr. Theodore S. Saad, Technical Editor
the microwave journal

Dear Sir:

This refers to your editorial in the S tember issue of the Microwave Journal. is very rarely, if ever, that I respond editorial comments, but I think the i you have presented is so good that I wo like to suggest you continue your effort

NEW PRODUCTS columns in the p have been extremely useful to the co ponents manufacturer and I believe to equipment designer as well. They were good, in fact, that the practice of releasi new products in this way has been abus as you have already indicated.

If you can stiffen the requirements publication in such a column, I think y will be doing a real service to the equ ment designers as well as for your adv tisers.

Very truly yours,
Ross Yeiter, *Manager*
Marketing Administrati
Semiconductor Operatio
CBS Electronics

• • •

Mr. Theodore S. Saad, Technical Editor
the microwave journal

Dear Sir:

In your August editorial you ". . . again why there is a shortage" of enginee

If there is really a shortage of engine — not just a shortage of low-priced gineers — the remedy is obviously to crease the incentives presented by t career.

The problem is not as you say, one "education, information and public re tions." Such propaganda efforts will f in the absence of adequate economic inc tives.

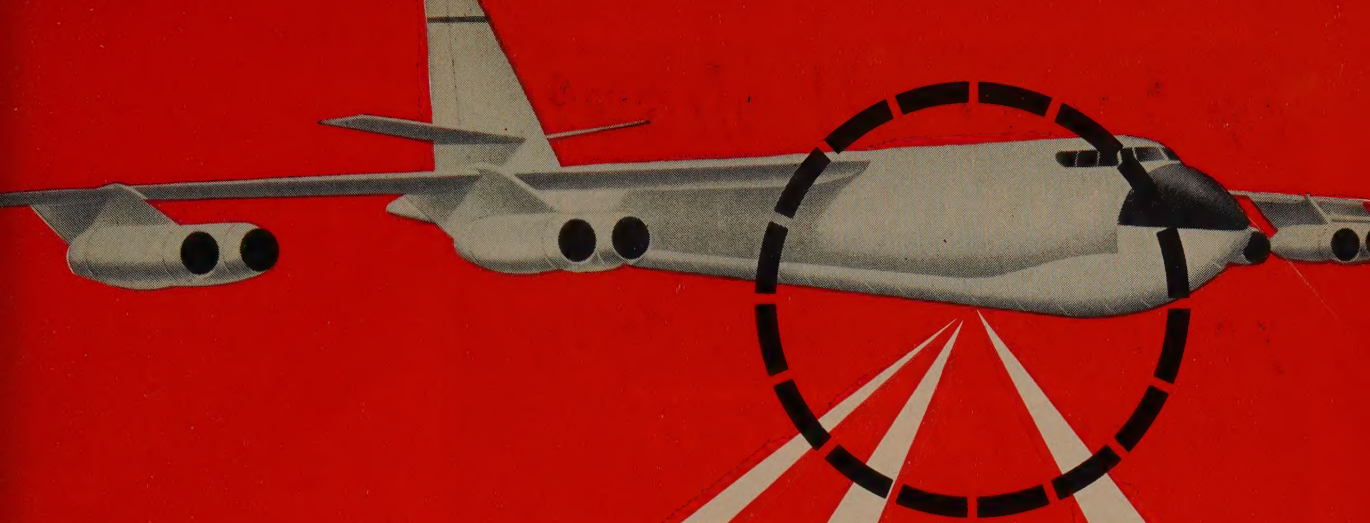
On the other hand, when parents, co sellors and students can see that engine ing offers rewards commensurate with hard studies required and with the va of the engineers' work, there will be difficulty in persuading an adequate numb of children to follow engineering course

Unfortunately, at present parents a counsellors cannot truthfully point to gineering as a career which provides e nomic recognition comparable to ot available professions nor to the value the work performed. This condition may verified by considering the financial con tion of the typical, capable experienced gineer today, in relation to men of simi calibre in other occupations.

I would, therefore, suggest that if are sincerely interested in increasing supply of engineers you should work increased economic incentives.*

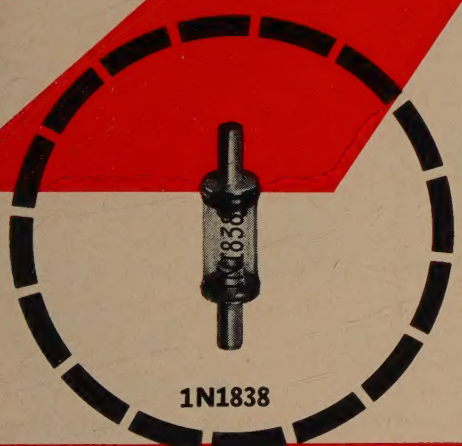
Very truly yours,
John R. Disston
Alexandria, Virgin

* This approach might, however, antagon some of your advertisers.



The first and only Germanium Mixer Diode

pecifically designed for ultra-low noise performanc in Doppler Radar



ELECTRICAL CHARACTERISTICS	
IF Test Frequency	20 kc.
RF Test Frequency	13,500 mc.
Overall Receiver Noise Figure (max.)	32 db.
Burnout	1.3 ergs.

For complete information write to — Special Components Department MJ 1159

This Philco mixer diode is uniquely designed for excellent, low-noise performance in Doppler radar receivers employing audio frequency IF amplifiers. Crystal noise output (flicker noise) is minimized in the 1 to 100 kc. range.

The RF test frequency is 13,500 mc., assuring high performance at either the 8,800 mc. or 13,500 mc. bands now being used.

Philco's exclusive bonded anchor whisker virtually eliminates microphonics. The 1N1838 is hermetically sealed and is designed and field-proven to meet the most stringent military environmental and electrical requirements. It is immediately available in production quantities.

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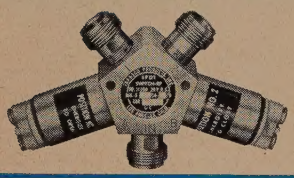
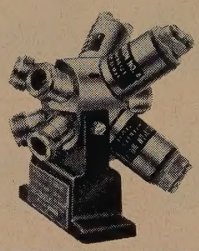
to know all about COAXIAL SWITCHES you need product data from TRANSCO

Transco makes more varieties of broad band Coaxial Switches than any other company. Here are some examples of our complete product line:

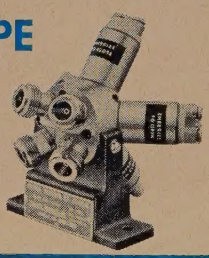
Y TYPE Solenoid Actuated SPST, SPDT



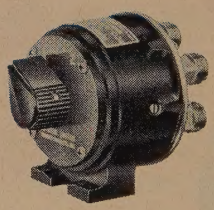


A TYPE Solenoid Actuated SP3T, SP4T

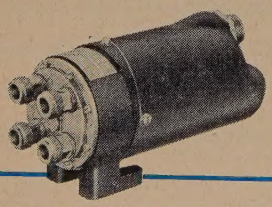
AX TYPE Solenoid Actuated Transfer

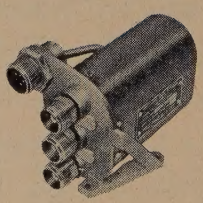


M TYPE Manual SPDT to SP6T, DPDT & Transfer



E TYPE Motor Actuated SPDT to SP6T, DPDT & Transfer



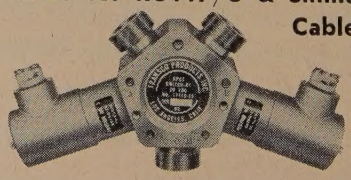


L TYPE Motor Driven Lobing Switch

Manufacturers and designers of microwave components and systems for transmission control. Send for complete product data.

Creative microwave engineers write for information about YOUR future with this progressive, well established firm.

YL TYPE Solenoid Actuated SPDT for RG117/U & Similar Cables



TRANSCO PRODUCTS INC.
12210 NEBRASKA AVENUE
LOS ANGELES 25, CALIFORNIA

LETTERS

Mr. Theodore S. Saad, Technical Editor
the microwave journal
Dear Sir:

I have just finished reading the comments on "Abuses of the New Product Features" in technical magazines. I would also like to add a few comments along these lines.

Perhaps I'm an optimist, but I believe that a strong force is already at work that will ultimately correct some of the abuses. The force of which I speak is the *impression* formed in the mind of the technical person when he analyzes the stated performance of a new product release. This person will, in most cases, have a "ballpark" or better knowledge of what the expected range of performance of the new product release should be. If the manufacturer makes such statements in a new product release that are unrealistic, the doubt will be formed in the mind of the technical reader as to the product performance and, in some cases, as to the sincerity of the manufacturer.

Let's look at the problem from the viewpoint of the manufacturer of a new product. He seeks to advertise his product to promote sales. Technical magazines, such as the Microwave Journal, are an excellent means of doing this. I feel that the manufacturer realizes that the people who read the "Journal" have a technical background. The manufacturer strives to create a favorable impression toward the new product release and his company. To accomplish these aims, and with the fact always present in his mind of the type of readers he will be dealing with, the manufacturer will be more and more careful to make realistic statements in regard to his products.

I believe the majority of manufacturers have adopted this policy of sincerity. Those who have not will find it increasingly more difficult to stay in business. Good workmanship, good will and sincerity are the prime tools of a successful business.

Respectfully,
Bob Thomas
Reseda, California

• • •

CHANGE OF ADDRESS

When requesting a change of address, please furnish the latest address at which you received *the microwave journal.* Allow one month for the change to become effective.

PAPERS

We wish to emphasize again that "the journal" is interested in receiving papers from the industry.

Papers can be addressed to: "the microwave journal," 160 Warren Street, Boston 19, Mass.

In the West Coast area, please address all papers to: "the microwave journal," Box 1134, Palo Alto, California.

Over 12,000 precision microwave components, in frequencies from 400Mc to 70 Kmc, are now available to you! MDL has all the junctions, mixers, hybrids, filters, circulators, bends, duplexers, joints and thousands of other adapters, terminations and additional microwave system components, you might ever need.

Because MDL is the leading supplier of precision microwave components, they meet your requirements — quickly, with electrically-tested and proven components. MDL assembles their components into sub-systems to your exact requirements, and MDL component-assemblies are superior, because they are designed to work together. MDL maintains extensive test facilities to insure that your MDL components, assemblies or systems fully meet your specifications, thus relieving you of further test responsibilities.

Start with MDL components — assure yourself of system performance from the start. All components are designed, engineered and manufactured to rigid specifications — the kind of quality control only a component specialist can give. Extensive inventory and production-run manufacturing assure quick delivery and economical pricing. New components are continually being developed and added to MDL's growing inventory.

When you design your microwave systems — design reliability and superior performance right into it from the start — select MDL components and be sure!

Send for complete literature.

Microwave Development Laboratories, Incorporated

92 Broad Street, Babson Park 57, Wellesley, Massachusetts. Tel: CE 5-6252

CIRCLE READER SERVICE CARD 7

Another RCA Contribution to Microwave Electronics

Economies in equipment size, weight, and power consumption begin with...

RCA PPM TRAVELING-WAVE TUBES

for X-Band *operation*

RCA Dev. Type 1140 PPM Traveling-Wave Tube—cut away to show self-contained periodic permanent magnets

RCA TRAVELING-WAVE TUBES FOR X-BAND OPERATION

RCA Type No.	Frequency (MC)	Typical Performance		Duty Factor	Focusing Method	Approx. Size	
		Power Output	Low-level Gain (db)			Weight (lb.)	Length (in.)
A-1140	8000-12000	10 mw	40	CW	PPM	5½	14
A-1133	8000-12000	1 w	35	CW	PPM	6	15
A-1181	7500-11200	50 peak watts	35	0.05	PPM	6	14

RCA Microwave-Tube Engineers invite inquiries for customized versions

RCA's continuing program to provide designers with a comprehensive and reliable line of traveling-wave tubes is exemplified by three new PPM focused X-band TWT's.

Focusing by means of Periodic Permanent Magnets makes possible more compact and lighter equipment designs. Waveguide couplings significantly reduce power loss, improve performance and efficiency in this complimentary family of developmental X-band traveling-wave tubes for ECM, drone target systems, and radar applications. And all three tubes are designed for high-altitude airborne operation.

For traveling-wave tubes in any application in the L, S, C, and X bands, call the RCA Field Office nearest you. Your RCA Field Representative will be happy to give you detailed information on RCA commercial and developmental types—or customized versions—for your specific system needs.

GOVERNMENT SALES

HARRISON, N. J.
415 S. 5th Street, HUmboldt 5-3900
DAYTON 2, OHIO
224 N. Wilkinson St., BAldwin 6-2366
WASHINGTON 6, D. C.
1625 "K" St., N.W., DIstrict 7-1260

INDUSTRIAL PRODUCTS SALES

DETROIT 2, MICHIGAN
714 New Center Building, TRinity 5-5600
NEWARK 2, N. J.
744 Broad St., HUmboldt 5-3900
CHICAGO 54, ILLINOIS
Suite 1154, Merchandise Mart Plaza, WHitehall 4-2900
LOS ANGELES 22, CALIF.
6355 E. Washington Blvd., RAymond 3-8361

RADIO CORPORATION OF AMERICA
Electron Tube Division *Harrison, N. J.*

NDUSTRY NOTES . . .

PARKER SEAL OPENS NEW R & D CENTER

Some 300 businessmen, engineers and dustrial leaders from all over the na- n attended the formal opening of rker Seal Company's new Research and velopment laboratory.

The new laboratory is said to be the st modern of its kind devoted exclu- ely to specialized seals and sealing oblems in aircraft, missiles and in- stry.

The establishment of the new facility rks the 3rd major expansion of Parker al Company in the last two years. Pre- usly this division of Parker-Hannifin rporation enlarged their facility in rea, Kentucky and acquired a new ilding in Lexington, Kentucky. The ter will be dedicated in a formal open- g November 6th.

The new research and development oratory is housed in a new 20,000 uare foot building alongside the main adquarters building at 10567 Jefferson vd., in Culver City. A part of the ea is also devoted to some administra- e offices and special processing. nong the products manufacutred by the mpany are O-ring seals for industry d military applications and a special e of static seals known as Gask-O-Seals exceptionally efficient sealing of high d low temperature and pressures of ses, oils and fuels.

• • •

$9 MILLION FORD GRANT TO M.I.T.

A $9,275,000 grant from the Ford undation, announced in Washington C., will be used by the Massachusetts stitute of Technology in making exten- e advances in engineering education, . Julius A. Stratton, President, said. The funds will support a program of velopment and innovation in the School Engineering under the direction of the an, Dr. Gordon S. Brown. Seven jor professorships in frontier areas of gineering are to be endowed, Dr. Strat- n said. Wholly new curricula will be roduced, new forms of instructional oratory equipment will be created, and ere will be an intensive effort to edu- e teachers as well as engineers for the portunities and responsibilities of the e.

• • •

WAVELINE EXPANSION

Waveline, Inc. of Caldwell, New Jersey nounces a general expansion program luding a 15,000 square foot building dition scheduled for completion by No- mber 1, 1959. According to James A. Gregor, President, the new building l be utilized for research and develop- nt, general engineering and produc- n facilities for the manufacture of spe- l microwave waveguide devices and crowave test equipment.

NEW MICROWAVE LIMITER

protects receivers against overload and burnout

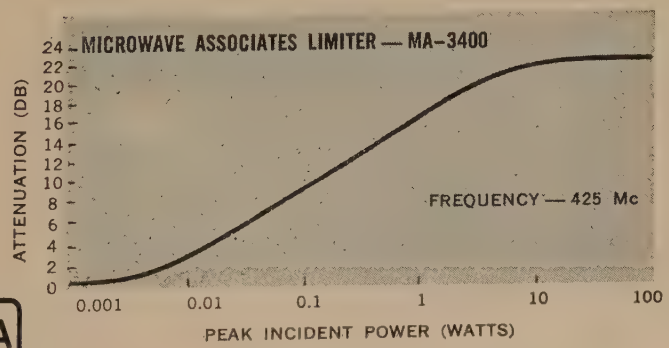
Another unique "first" from Microwave Associates, Inc., is this family of all-new solid state devices, which requires no external bias and are self-limiting devices. It is the simplest way yet to give radar and communication receivers needed protection.

The specifications chart and performance curve below tell you all you need to know to evaluate its capabilities. The two models are typical of units which can be designed for your applications at other frequencies. The package has female Type N coaxial connectors, for input and output.

Today for UHF . . . tomorrow for higher frequencies.

SPECIFICATIONS

	MA-3400	MA-3401
Frequency (center)	425 ±5%	600 ±5%
Low Level Insertion Loss	0.3 db	0.5 db
Peak Power	400 watts	200 watts
Duty Cycle	.002	.002
High Level Insertion Loss	20 db	20 db



MICROWAVE ASSOCIATES, INC.

BURLINGTON, MASSACHUSETTS • Telephone: BRowning 2-3000

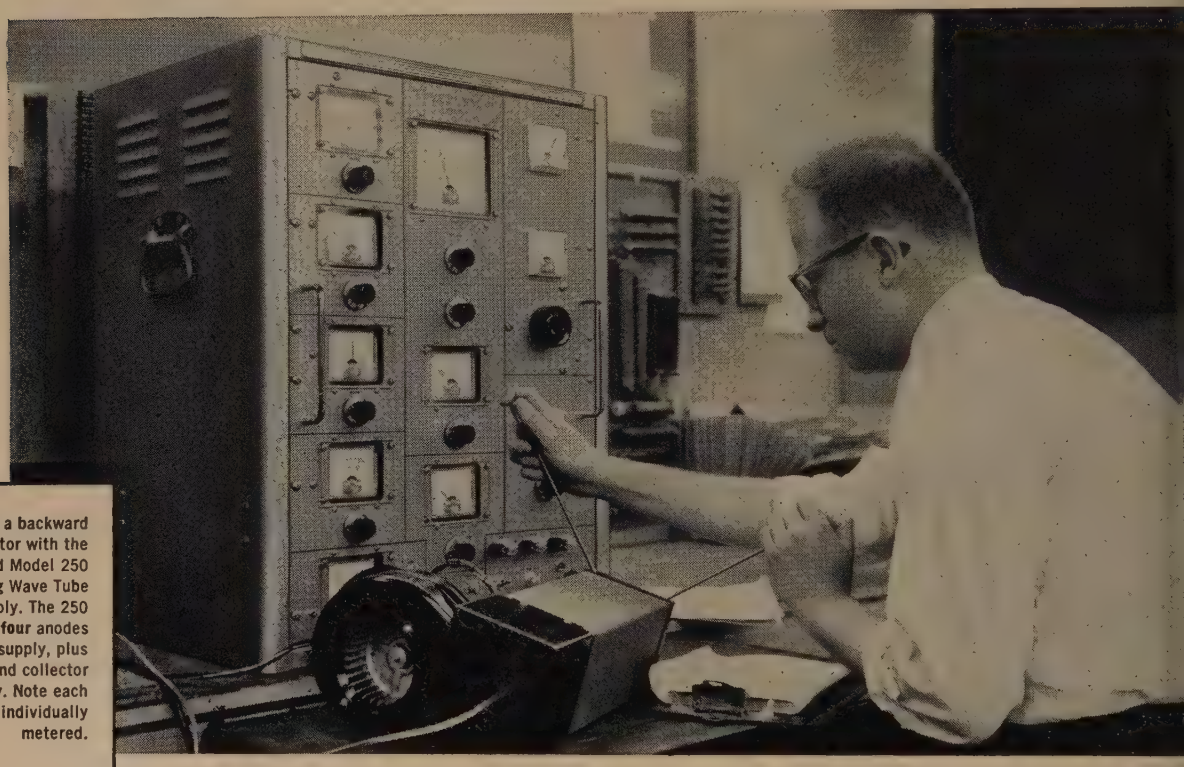
CIRCLE READER SERVICE CARD 8

Power your TWTs and BWOs with the ALFRED 250

ALFRED's versatile Model 250 will operate more low-powered and low noise TW tubes than any other commercially available power supply. It operates most medium-powered traveling wave tubes as well. High regulation, low ripple and low drift make the Model 250 an ideal standard for testing and evaluating tubes, backward wave oscillators and carcinatrons.

Here's another remarkable feature: all electrode supplies are isolated from ground and connections brought out to rear patch panel. Most presently known grounding and modulation arrangements for TW tubes can be used.

Alfred's design protects both operator and tube. A "helix over-current relay" trips at full scale at any range and shuts off all high voltage supplies. All meters are isolated from panel for operator safety.



Aligning a backward wave oscillator with the Alfred Model 250 Traveling Wave Tube Power Supply. The 250 features four anodes and grid supply, plus helix and collector supply. Note each supply is individually metered.

TUBE EVALUATION

Send us your tube type specifications. Alfred Electronics will be happy to evaluate them and advise whether the Model 250 will operate your tube.

Alfred Electronics offers the industry's most complete line of packaged traveling wave tube amplifiers. Write for new short form catalog.

Dept. 6811

ALFRED ELECTRONICS

897 COMMERCIAL STREET
PALO ALTO, CALIFORNIA

BRIEF SPECIFICATIONS

HELIX SUPPLY	
Voltage	90 to 3500 v, range switch and 10 turn vernier
Current	0 to 5 ma to helix 0 to 60 ma to collector
External Modulation	Direct or capacitively coupled
PROTECTION	Overcurrent relay shuts off all high voltage supplies
COLLECTOR SUPPLY	
Voltage	0, +150, +250 v, relative to helix
Current	0 to 60 ma
GRID SUPPLY (relative to cathode)	
Voltage	0 to −150 v
Current	.1 ma average
External Modulation	Direct or capacitively coupled

ANODE SUPPLIES (relative to cathode)		
	#1	#2
Voltage	0 to + 450 v	0 to + 300 v
Current	0 to 20 ma	0 to 1 ma
	#3	#4
Voltage	0 to +750 v	0 to 2500 v
Current	0 to 1 ma	0 to 1 ma
HEATER SUPPLY		
Voltage	0 to 10 v ac	
Power	20 va maximum	
SOLENOID SUPPLY		
Voltage	0 to 100 v	
Current	0 to 7 amperes	
BLOWER SUPPLY		
Voltage	115 v ac or 28 v dc	
Current	0 to 1 ampere ac or dc	
PRICE	$1990 F.O.B. Palo Alto	

NDUSTRY NEWS

LVANIA NAMES DAVID H. SIMON ANAGER OF ADVERTISING AND MERCHANDISING FOR SPECIAL TUBE OPERATIONS

The appointment of David H. Simon advertising and merchandising man- r of Special Tube Operations, Syl- ia Electric Products Inc., has been nounced by Thomas D. Fuller, market- manager of Special Tube Operations. n his new position, Mr. Simon will responsible for all advertising and rchandising functions for the micro- ve and special purpose components ivities of the Special Tube Operations ilities in Mountain View, and in Wil- nsport, Pa.

A native of Washington, D.C., Mr. non received a Bachelor of Electrical gineering degree from Cornell Uni- sity in 1954, and subsequently served ee years as a Naval officer. In 1957, joined Sylvania's Special Tube Opera- ns in Woburn, Mass., with responsi- ity for various advertising assignments. n October 1958, he was transferred to untain View to handle advertising ivities for the Special Tube Opera- ns facilities here. Mr. Simon is a mber of the San Francisco Chapter of National Industrial Advertisers As- iation and the Institute of Radio gineers.

• • •

TACO TEST RANGE OPENED

Technical Appliance Corporation, of rburne, N.Y. on October 14, 1959, cially opened a new antenna test fa- ty, which company officials say is one the most complete installations of its d in the antenna industry.

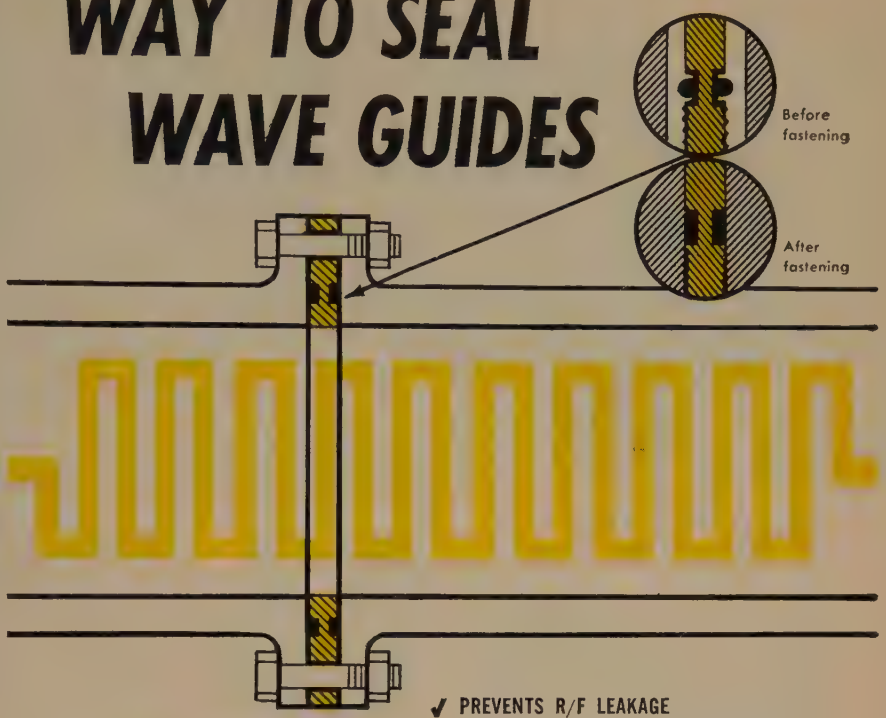
The range is located near the com- y's plant in Sherburne, in upper New rk state farming country. The test ge extends more than three thousand t between receiver and transmitter lo- ions, which are on elevations of 300 t above an intervening valley. These graphical conditions, coupled with a h degree of freedom from man-made erference, permit measurements of an- na characteristics under conditions that roach "free space."

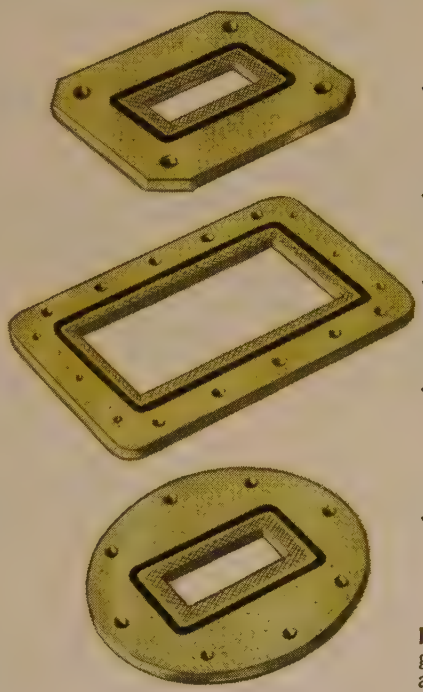
The range is currently in use for de- opment and check-out of commercial military antennas. Equipment is ilable at the range for reception, nsmission, and measurement at all fre- ncies from VHF through X-band.

Taco manufactures VHF and UHF ennas for TV reception, and designs manufactures antennas for point-to- nt communications, telemetering, ra- and tracking applications, as well more specialized antenna equipment the military.

Mr. Herbert Browne, President and Tore Lundahl, Vice-President of o, and other company officials pointed that the characteristics of the new ge will provide faster, more accurate ineering data on all Taco military and mercial antenna development projects.

NOW THERE IS A BETTER WAY TO SEAL WAVE GUIDES





✓ **PREVENTS R/F LEAKAGE**
Metal-to-metal contact with "engraved fingers" on inside surfaces assures electrical continuity.

✓ **PROVIDES NO-LEAKAGE SEALING**
Controlled confinement of seal gland assures safe, sure, positive sealing — **exceeds** top hermetic specs!

✓ **ELMINATES ARCING AND/OR BURNING**
Designed to exacting requirements for proper mating of flanges as specified.

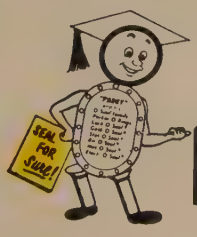
✓ **CAN BE RE-USED**
Seal is never "squeezed" beyond elastic limits, "memory" is constant, before, during and after fastening.

✓ **ECONOMICAL**
Eliminates cleaning or resurfacing flanges, no intricate machining required to accommodate the seal, and they're resuseable with just normal care.

✓ **STANDARDS FOR W/R SERIES**
Electr-O-Seals are available as standards to WR series Wave Guide flanges, assuring adequate supply and economy.

In addition to the standard WR series wave guide flange seals, Parker Seal Company also makes special seals to meet almost any specification or configuration. A nation wide group of field engineers are available to aid in expediting your requirements.

For more complete information send for catalog 5801.

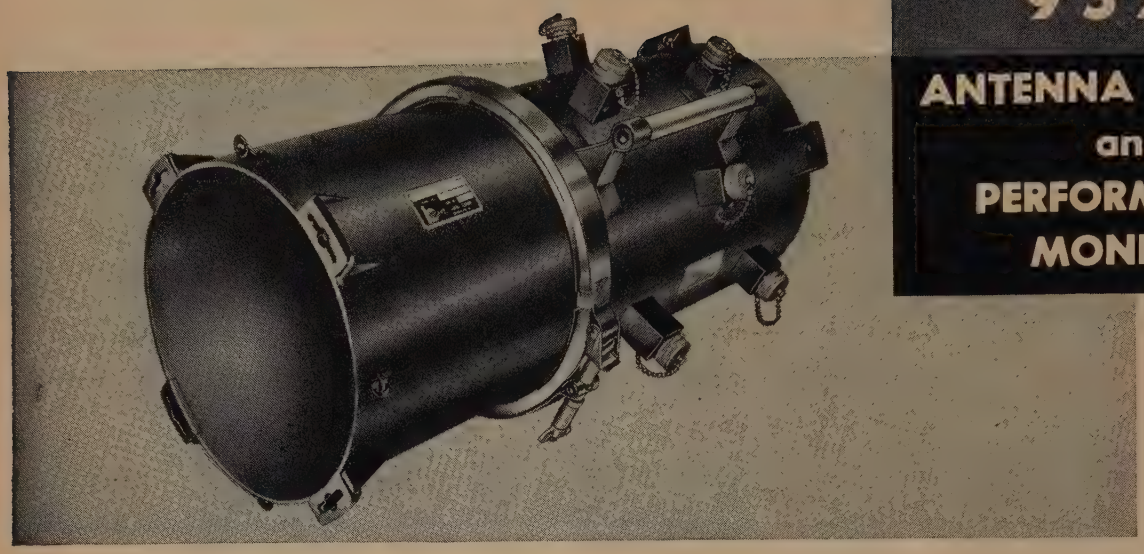


Parker SEAL COMPANY
Culver City, California and Cleveland, Ohio
A DIVISION OF PARKER-HANNIFIN CORPORATION

CIRCLE READER SERVICE CARD 10

9322

ANTENNA COUPLER and PERFORMANCE MONITOR



MODEL NO. 9322

The Bogart Model 9322 Antenna Coupler and Performance Monitor is the outgrowth of a design program to develop a pre-flight check-out device utilizing lossy paint that could be used to **monitor an entire system, from magnetron through antenna.** Ordinarily, power and frequency checks are made looking **into** the antenna. Losses in the antenna itself are not checked.

The Bogart Applications Engineering Group developed a lossy paint which could be deposited on the inside of a radome type shield. The carbon-deposited horsehair materials now in use were found to be unsatisfactory for practical usage. They did not radiate heat, but fed heat back to the antenna, sometimes damaging the antenna itself; they were not suitable for outdoor use; they were suitable only for low-power usage; they were extremely frequency-sensitive; they had a limited life requiring frequent replacement and they were expensive. The Bogart LP* material has the heat conductivity of a metal, is exceptionally broadband, can be "weathered" indefinitely, will accept high power without deterioration, and is a comparatively inexpensive material.

The Model No. 9322 was designed for a specific radar installation. In this case, it was desired to measure the characteristics of a radar **through** the antenna, as well as to absorb the RF energy and prevent harmful radiation.

Coupling devices were designed by Bogart to permit measurements of the power out, frequency, spectrum analysis, and sweep rate, from the outside of the aircraft. The foregoing is a simple illustration of a single use of the Bogart Lossy Paint material.

The Bogart Applications Engineering Group would be pleased to discuss the uses of LP* material for your particular requirements. As examples of its current applications, this material has been used for various shapes of antenna couplers, lossy backplates on high power filters, and lossy transmission lines.

ANTENNA COUPLER APPLICATION

Frequency Range (Kmc/s)	Average Power Watts (CW)	VSWR††	Approx. Length (Inches)	Approx. Width (Inches)	Approx. Height (Inches)	Approx. Weight (Lbs.)
1.00 - 11.00	500	1.15	22-1/2	9-1/2	12	20

PERFORMANCE MONITOR USE

Frequency Range (Kmc/s)**		Coupling (db + 2.5)
1.00	1.50	40
1.50	2.40	40
2.40	3.60	40
3.60	7.30	40
7.00	8.80	40
8.70	10.50	40

(*) Lossy Paint

(††) The VSWR indicated is the difference seen by a circularly polarized antenna when "looking" into free space and into the Bogart Model No. 9322.

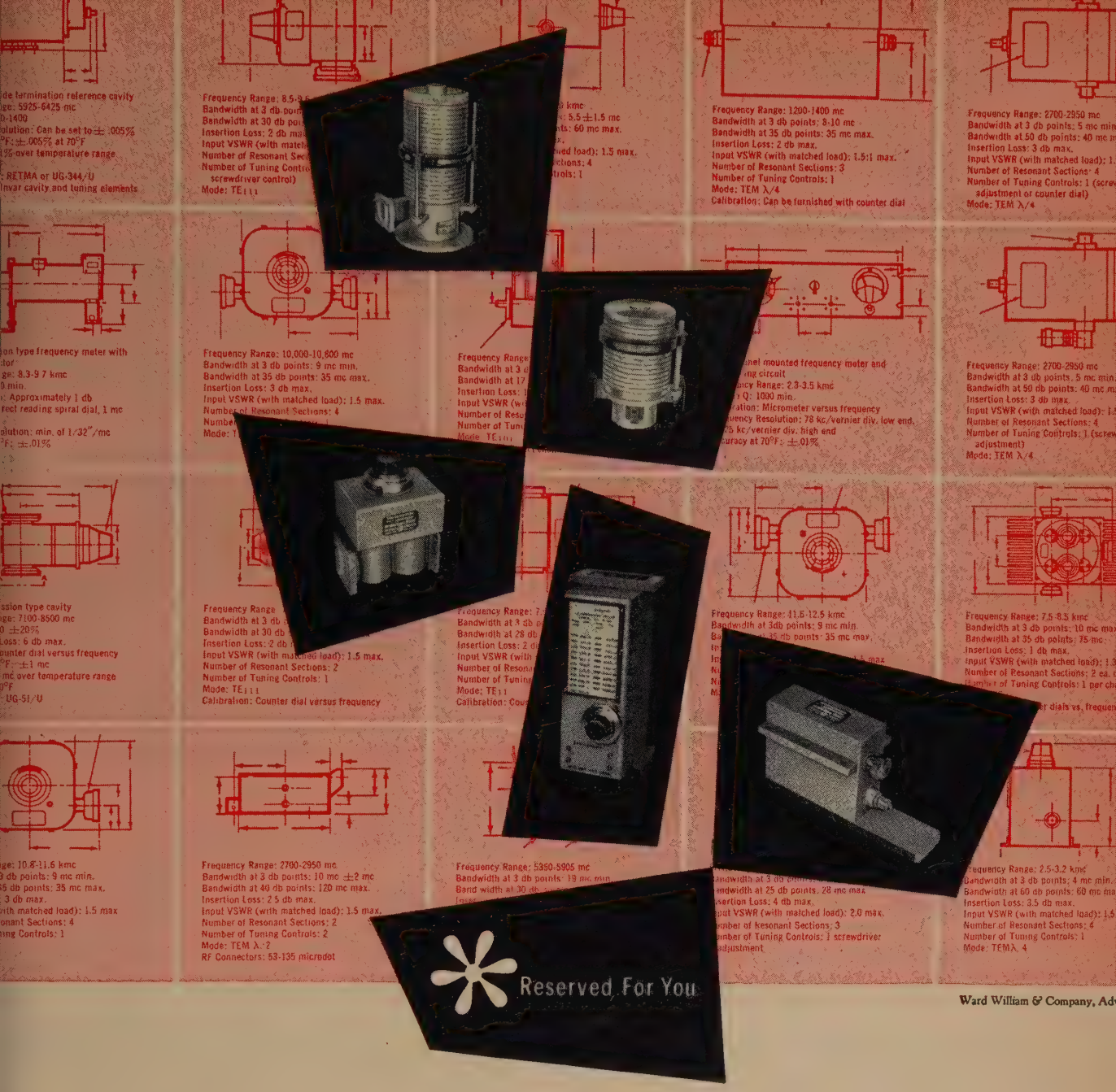
(**) Coupler Band Division

BOGART

BOGART MANUFACTURING CORPORATION

315 Seigel Street — **Brooklyn 6, New York**

serving the electronics industry since 1942 — design • development • production



Ward William & Company, Ad

over 400 microwave frequency meter or filter designs

With hundreds to choose from, you can select the microwave frequency meter or tunable band pass filter to meet your exact requirement. If the unit you need is not already in stock, it can be produced readily by *modifying* one of the Frequency Standards meters or filters now *available*. This means both minimum lead time and development costs. Send your technical requirement for a prompt analysis or meet with our staff to discuss your specific problem.

Literature on Standard Products Available on Request

FREQUENCY STANDARDS

Division of Harvard Industries, Inc.
Box 504, Asbury Park, New Jersey
Phone: PRospect 4-0500
TWX A PK 588

Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON COMPANY, WALTHAM 54, MASS., Vol. 1, No. 8

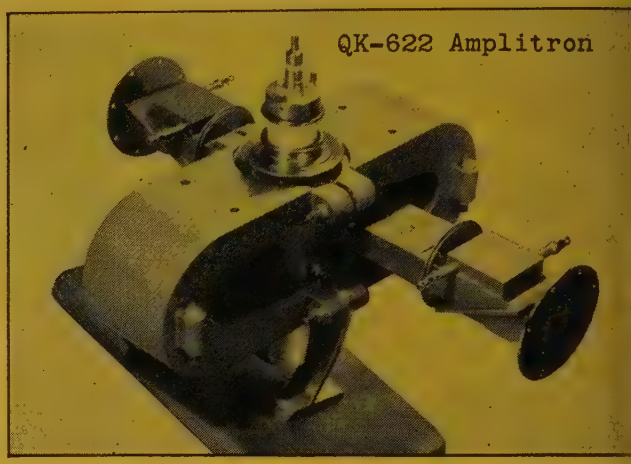
NEW RAYTHEON HEATERLESS AMPLITRONS EXCEED 1,000 HOURS AT RATED POWER OUTPUT

Two new 3-megawatt, S-band Amplitrons have demonstrated an operating life of more than 1,000 hours at rated power output. The QK-622 covers the 2,900 to 3,100 Mc band; the QK-783, the 2,700 to 2,900 Mc band. Both tubes supply full power with low phase pushing characteristics over their entire operating bands at efficiencies greater than 70%--making them unquestionably the most highly efficient microwave tubes thus far developed.

Tubes may be operated at reduced peak power levels to serve as driver stages. High efficiencies are retained at peak power of 600 Kw and gain of 10 db.

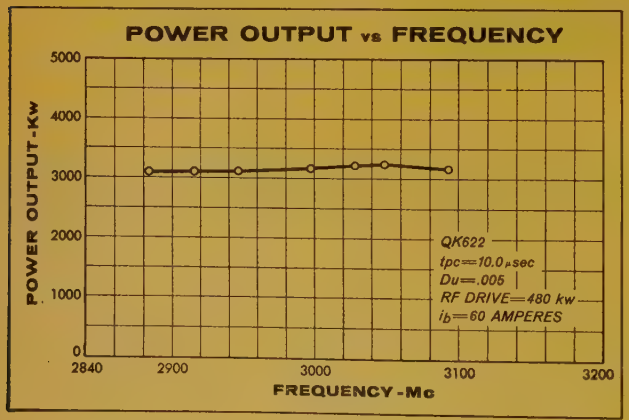
Exceptionally long tube life is made possible by the fact that no cathode warmup is required. Starting takes place whenever RF input is present prior to application of modulating pulse. Heater supplies may be omitted entirely from the equipment.

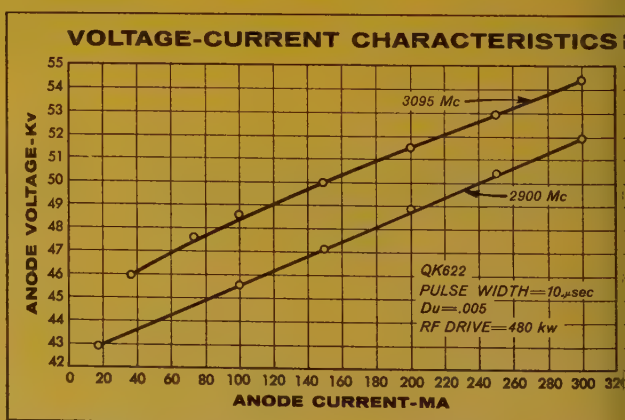
Applications include power-amplifier stages for long-range radars. The tube has been used successfully as an RF power source for linear accelerators.



Typical Operating Characteristics
(QK622 and QK783 Amplitrons)

Peak Power Output (min.)	3 Mw
Average Power Output	15 Kw
Pulse Duration	10 μ sec
Band Width	200 Mc
Duty Cycle	.005
Pulse Voltage	50-55 Kv
Peak Anode Current	65 amps
Efficiency	70%
RF Input	475 Kw
Weight (with permanent magnet)	125 lbs.





Excellence in Electronics

RAYTHEON

You can obtain detailed application information and special development services by contacting: Microwave and Power Tube Division, Raytheon Company, Waltham 54, Massachusetts

A LEADER IN CREATIVE MICROWAVE TECHNOLOGY

RCHITECT OF MICROWAVE ELECTRONICS . . .

R. RUDOLPH KOMPFNER

BELL TELEPHONE LABORATORIES
MURRAY HILL, NEW JERSEY

"Science is my hobby. It always was and it always will ."

Forcefully spoken by 50-year old architect-turned-scien-t, Dr. Rudolf Kompfner, director of electronic and dio research at Bell Telephone Laboratories, these words m up his attitude towards his profession.

Slight of stature, with eyes that twinkle merriment and od humor, possessed of an abundant amount of patience d cordiality, Dr. Kompfner is the inventor of the trav-ing wave tube. For this oustanding contribution to micro-ave electronics he received the 1955 Duddell Medal from e Physical Society of England. A very high honor, it has eviously been bestowed on men of such caliber as the niversity of California's Ernest O. Lawrence, of cyclotron me, and Scotland's C. T. R. Wilson, inventor of the cloud amber — both Nobel Prize winners in physics.

Some of Dr. Kompfner's lesser known work in the mi-owave field includes the backward wave oscillator, ferrite olators for traveling wave tubes, the use of coupled hel-es, and slalom focusing. He also played a significant part promoting work on the solid-stater maser and the para-etric amplifier.

That a man who was once a professional architect should day be one of the free world's leading architects of mi-owave electronics, is a rare coincidence. This rarity is rsonified in Rudolf Kompfner, a person of many facets. nd it's as interesting as it is informative to briefly trace t his remarkable career.

Vienna-born "Rudi," as his associates call him, came to nerica and Bell Telephone Laboratories by a circuitous, not adventurous, route. In fact, were there one word that scribes his life up to now, that word would be, "uncon-ntional."

As a boy in his native Austria, Dr. Kompfner was equally terested in science and architecture. But by the accident having an uncle who was an architect, he graduated om Vienna's *Technische Hochschule* with an engineering gree in architecture. This was in 1933. Today, with his epressible sense of humor, Dr. Kompfner says of the cident: "If my uncle had been instead a scientist, I ould have become a scientist."

In the following year, 1934, he journeyed to England to ntinue his architectural studies. During the ensuing riod his latent leadership ability asserted itself. For in 37, when only 28 years old, he became director of a ndon building firm.

Then in quick succession, came the chain of events that turned him from a successful career in architecture to an even more successful one in science.

Dr. Kompfner's hobby — science — began to engage more of his interest than ever before. He devoted much of his spare time to studying television, radio, and physics. Evenings he spent reading deeply of these subjects in the London Patent Office Library, an archive of one of the world's largest technical collections.

He became so engrossed with some of the problems of high frequency electronics that, while still practicing architecture, he wrote a paper on velocity modulation. This was the single act that would later trigger his professional career as scientist.

An English engineer, a friend, saw the paper and asked, "Why don't you publish this?" Dr. Kompfner did just that. In 1940 his very first scientific paper appeared in the British Journal *Wireless Engineer*. "I even got paid at the rate of a guinea a page for it," he recalls now.

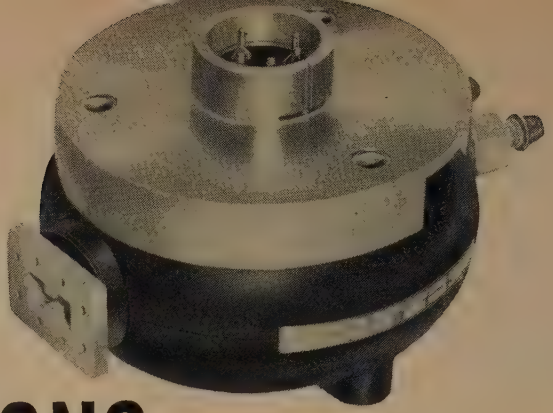
In the previous year, the armies of Adolf Hitler — a former building-trades laborer with somewhat different aspirations — had occupied the republic of Austria. Automatically, all Austrians became citizens of the Third Reich, the new Germany. As a result, when Britain declared war on Germany in September of 1939, Dr. Kompfner, being technically an enemy alien, was interned.

This internment lasted six months. But while a man of Kompfner's mien severely disliked having his personal liberty curtailed even for that short a period, he nevertheless managed to turn it to good advantage: further pursuit of the hobby he loved.

Interned along with him in a large hotel encircled with barbed wire, was a group of scientists. Immediately they began organizing seminars and lectures which Kompfner attended with zeal. "I had a six months' concentrated course in science," he reflects. "We were improving ourselves all the time."

At the end of this period, the London building firm that employed Kompfner managed to secure his release from internment. And for approximately the next year he once again practiced the profession of architecture.

(*Continued on page 19*)



SMALLEST LIGHTEST CARCINOTRONS

with wide band sole tuning

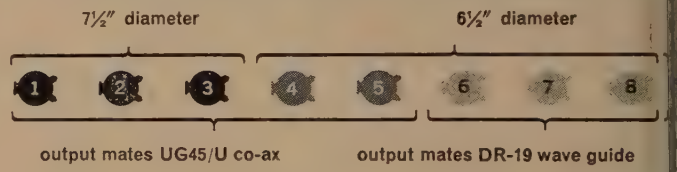
Though it has just recently made its debut into the high society of Litton microwave tubes, this carcinotron (our model L-3298) has already been commended by the military for its exceptionally clean design. Every engineer concerned with upgrading the performance of ECM equipment will surely find much of interest in this medium-power tube, with which Litton takes a major stride toward truly simultaneous noise-jamming capability by affording faster tuning rates than any previously attainable.

The Litton family of eight electrically-compatible carcinotrons is the first to incorporate the critical capability of wide band sole tuning without frequency or power holes when the tube is operated into as much as a 1.5-to-1 mismatch. Litton carcinotrons are the first to use wider-than-normal-band RF output couplers, minimizing many system components such as antennae, waveguide plumbing, and load isolators.

We cite these firsts not for glory's sake, but rather for their meaningful contribution to more efficient system design, smaller size and lighter weight.

The notable suitability of these carcinotrons is not limited to ECM. You can also consider them for other military applications such as drivers for communications links—in fact, wherever medium-power tubes with extremely rapid tuning and low tuning power are required.

Because of their mechanical and electrical compatibility the eight tubes in the family are interchangeable, as shown.



These versatile tubes are not just drawingboard products—you can order them now.

Write concerning voltage-tuned power oscillators of whatever nature to Litton Industries, Electron Tube Division, Office M8, 960 Industrial Road, San Carlos, California. Your request for our Carcinotron Catalog or for answers to your specific questions will be honored promptly.

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LITTON INDUSTRIES Electron Tube Division

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CAPABILITY THAT CAN CHANGE YOUR PLANNING

r. Kompfner addresses special dinner for National Engineers' Week in February 1959, which was arranged by Winston-Salem Council of Engineering Societies.

r. Rudolf Kompfner

(*Continued from page 17*)

Then, in 1941, his scientific career began in earnest. People with a knowledge of microwave electronics were short supply at that critical time. And the British Admiralty, combing through the technical literature, came ross Rudolf Kompfner's article in *Wireless Engineer.* ortly, as a Temporary Experimental Officer, he entered itish Admiralty service, and soon found himself in the ysics department of Birmingham University. Here he orked on the development of microwave tubes, such as ystrons. In fact, it was his concern for what he considered a "weakness" in the latter that led to his invention the traveling wave tube while at that institution.

In 1944, still under the auspices of the British Admiral- Kompfner found himself in the physics laboratory of xford University, continuing his work on the traveling ave tube and other problems in microwave electronics. special arrangement, he was able to pursue his doctoral esis, and in 1951 he received his Ph.D. in physics from xford.

It was during this venture at Oxford that Bell Telephone Laboratories became interested in Rudolf Kompfner.

The Laboratories' John R. Pierce, now director of research in communications principles, was also working in e field of microwave tubes. Pierce had seen a report by ompfner, one given restricted distribution by the Admiry to Britain's wartime allies, and was quite impressed.

Thus in 1947, through the recommendation of John erce, an invitation was issued Rudolf Kompfner to come the United States and join Bell Telephone Laboratories. Except for circumstances beyond his control, Dr. Kompf- would have come immediately. Because of U.S. immiation laws, however, he could only be admitted to this untry under the Austrian, not the British quota. He ited. Several years passed. Meantime, he spent a considble part of his time with the Admiralty's Services ctronics Research Laboratory, and also served as contant to the English Electric Valve Company on travel- wave tube development.

Finally, on December 19, 1951, Rudolf Kompfner set l for the United States.

"Better late than never," he now says philosophically. "Coming to America was my happiest decision."

Kompfner was, and remains, very content with his work at the Laboratories. "I'm doing what I like to do. If I could afford it, I'd work without a salary."

Upon arrival here he joined Bell Telephone Laboratories as a member of the technical staff. Four years later, in 1955, he was named director of electronics research. And in 1957, he took over his present function as director of electronic and radio research.

Just recently, "Rudi" Kompfner bought a house in suburban New Jersey. It is a country-like setting. He and his family — his British-born wife Peggy and their two children — enjoy it immensely. Yet ironically, for a man who has contributed so much to the science of communication, this is the first house and land he ever owned. Kompfner's mirthful comment on this, his latest acquisition of material wealth: "I am now the possessor of 1-1/4 acres of poison ivy."

Theirs is one household, however, that apparently won't be enslaved by the "happy screen," at least in the foreseeable future. For in his frank, forthright, and ever-humorous but meaningful vein, Rudolf Kompfner asserts, "We don't own a TV set. And it is my firm intention of never having one in my home." This is hard on the children, he admits, but he can't stand the commercials. He doesn't think the technical or programming quality is sufficiently good, either.

Rudolf Kompfner's interests can be summed up in one word: microwave electronics. He's currently engaged in a project of communicating by radio between California and New Jersey, by means of a passive earth satellite. Besides its value in communication across oceans, he sees microwave electronics playing an important role in the exploration of space. To make this possible, he thinks higher and higher frequencies will have to come into use, plus greater and greater sophistication of concepts, systems and hardware.

Looking back over his career, what does this unconventional man Rudolf Kompfner, this ardent lover of science for itself, have to say? In his inimitable fashion, he observes, "My only regret is that I wasted seven years of my life in architecture, whereas I should have studied more physics and mathematics!"

HOW TO FIND THE BEST ANSWER TO YOUR NOISE SOURCE PROBLEMS!

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Bendix® Noise Source Tubes are free from ambient temperature corrections and offer unusually long life and stability—the result of designing and manufacturing to tolerances far beyond the ordinary.

Whatever your noise source problem, be sure to check with our specialists for the best answer. Write today and ask for complete information regarding any specific applications you have.

Freq. Range KMC	Band	Waveguide Number	Bendix Type Number	RETMA Type No.	Mount Type	Recommended Mode of Operation (Note 2)	Anode Current Ma (Note 1)	Tube Drop Volts (Note 1)	Tube Excess Noise Ratio DB (Note 3)
1.12-1.70	L	RG-69/U	RXB103085		10°E	D.C.	250	130	15.2
			TD-21	6881	90°H	D.C.	250	65	15.2
			TD-29	7101	90°H	A.C. and D.C.	250	130	18.0
			TD-33		90°H	A.C. and D.C.	250	75	15.2
2.6-3.95	S	RG-48/U	TD-12	6358	10°E	D.C.	250	80	15.2
			TD-22	6782	90°H	A.C. and D.C.	250	45	15.2
			TD-31		10°E	A.C. and D.C.	250	85	15.2
			TD-32		10°E	A.C. and D.C.	250	170	18.0
			TD-34		10°E	D.C.	250	165	18.0
			TD-35		90°H	A.C. and D.C.	250	80	18.0
			TD-38		10°E	PULSE*	200	145	15.2
3.30-4.90	S	WR-229	TD-24	6852	10°E	A.C. and D.C.	250	65	15.2
			TD-30		10°E	A.C. and D.C.	250	110	18.0
3.95-5.85	C	RG-49/U	TD-10	6356	10°E	D.C.	250	70	15.2
			TD-39		10°E	PULSE*	175	135	15.2
			RXB103422		10°E	D.C.	250	110	18.0
5.85-8.20	X	RG-50/U	TD-10	6356	10°E	D.C.	250	70	15.2
			TD-39		10°E	PULSE*	(200)	(130)	15.2
			RXB103422		10°E	D.C.	250	(110)	18.0
8.20-12.40	X	RG-52/U	TD-11	6357	10°E	D.C.	200	75	15.2
			TD-23	6882	10°E	D.C.	200	115	18.0
			TD-40		10°E	PULSE*	175	130	15.2
			TD-44		10°E	PULSE*	175	260	18.0
			RXB103093		90°H	D.C.	200	(35)	15.2
			RXB103394		90°H	A.C. and D.C.	(100)	(50)	15.2
12.4-18.00	Ku	RG-91/U	TD-18	6684	10°E	D.C.	200	70	15.2
			TD-54		10°E	D.C.	200	130	18.0
			TD-55		10°E	PULSE*	175	230	18.0
			RXB103409		10°E	A.C. and D.C.	(100)	(65)	15.2
			TD-41		10°E	PULSE*	175	130	15.2
			TD-46		20°E	A.C. and D.C.	100	35	15.2
			RXB103254		90°H	D.C.	200	(40)	15.2
18.0-26.5	K	RG-53/U	TD-13	6359	10°E	D.C.	200	65	15.2
			TD-50		10°E	D.C.	200	125	18.0
			TD-42		10°E	PULSE*	175	125	15.2
			RXB103411		90°H	A.C. and D.C.	(100)	(50)	15.2
26.5-40.0	Ka	RG-96/U	RXB103251		10°E	D.C.	125	130	15.2
			RXB103509		10°E	PULSE*	100	175	15.2

NOTE 1: Anode current and tube drop are D.C. values. Values in parentheses are tentative.

NOTE 2: D.C. operation—Cathode at one end only.
A.C. and D.C. operation—Cathodes at both ends.
Pulse operation—Cathode at one end specially designed for pulse operation.

NOTE 3: The Excess Noise Ratio in DB is 10 log $\left(\frac{T\,eff}{290} - 1\right)$

*If the anode current during the "on time" of a square pulse (of greater than 100 micro sec. duration) is nominally the same as the rated D.C. anode current, the tube drop during this period will be approximately the same as the rated D.C. tube drop.

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Canadian Distributor: Computing Devices of Canada, Ltd., P.O. Box 508, Ottawa 4, Ontario

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CIRCLE READER SERVICE CARD 15

INDUSTRY NOTES

1960 WINTER CONVENTION ON MILITARY ELECTRONICS

A 1960 Winter Convention on Militar Electronics will be conducted on the W Coast for the first time by the Institu of Radio Engineers, February 3-4-5, at t Biltmore Hotel, Los Angeles, accordi to Dr. Lester C. Van Atta, Chairman of t Steering Committee.

Sponsor for the event is the Profession Group on Military Electronics with t Los Angeles Section acting as host.

Plans are being formulated for both e hibits and technical sessions program well as a schedule of special events, fie trips and women's activities.

Besides Dr. Van Atta of Hughes Air craft Company as general chairman, t Convention Committee includes: Dr. Ro bert C. Hansen of Hughes Aircraft as a sociate general chairman; Burgess Dempst of Electronic Engineering Company chairman of the Advisory Committee; Go don B. Knoob of Motorola, Inc., and Dr Henry L. Richter of Jet Propulsion Labor tories as chairman and associate chairm of the Technical Program Committee; Ein Ingebretsen of Summers Gyroscope an Charles C. Olsefsky of Missile Systems Di vision, Lockheed Aircraft Corporation chairman and associate chairman of t Exhibits Committee; Fred J. MacKena of Consolidated Electrodynamics and Spe cer B. Varian, consultant as chairman an associate chairman of the Arrangemen Committee; and Richard W. Larrick an Warren E. Northwood of Space Technol gy Laboratories, Inc., as chairman and a sociate chairman of the Public Relatio Committee.

Advisory Committee members are: Bru S. Angwin, Los Angeles Section IRE mem ber on the Board of the Western Elec tronic Show and Convention; Robert Geffs, regional vice president, America Ordnance Association; C. F. Horne, Re Admiral, USN (Ret.); John Inwood, pre dent, Southern California Chapter, Arme Forces Communications and Electronics As sociation; Arthur R. Laufer, chairman, Na tional Executive Committee, Infrared In formation Symposia; Walter E. Peterso Los Angeles Section IRE member on WE CON Board of Directors; Henry Randal chairman, National Professional Group o Military Electronics, IRE; Louis A. D Ter Veen, vice chairman, National Pro fessional Group on Military Electronic IRE; and A. B. Vosseller, vice admira USN (Ret.).

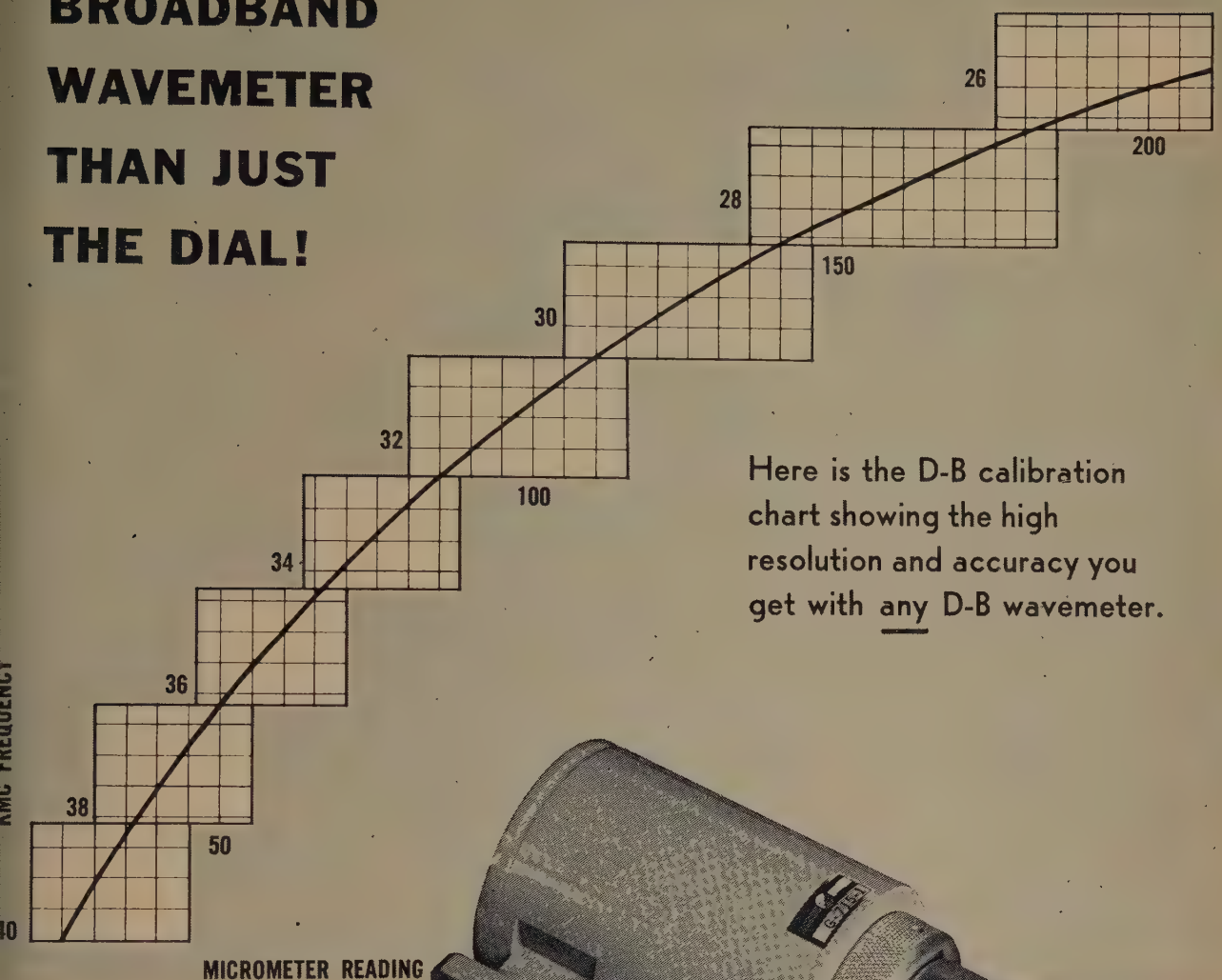
• • •

ELECTRONIC COMPONENTS AND PARTS PRIORITIES REGULATIONS CHANGED

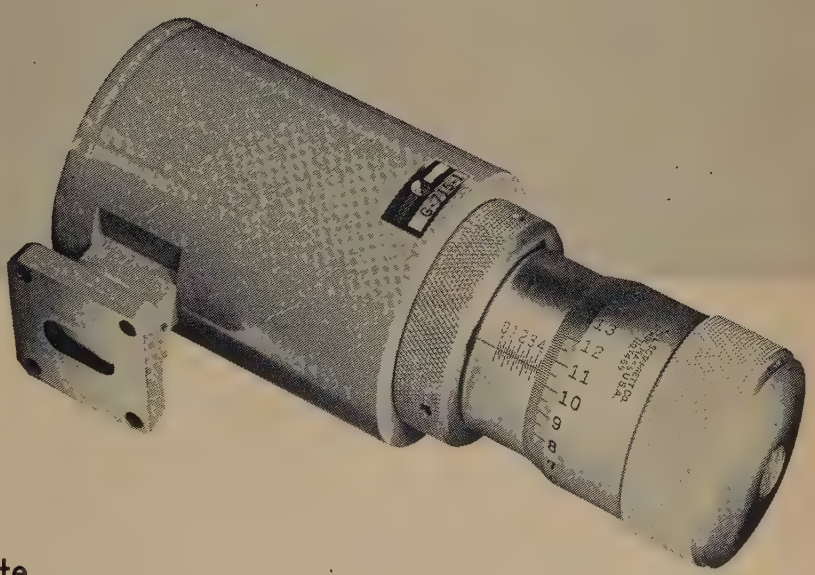
The Business and Defense Services Ad ministration, U.S. Department of Com merce, today announced a change in th priorities regulations covering electron

(*Continued on page 22*)

THERE'S MORE TO A D-B BROADBAND WAVEMETER THAN JUST THE DIAL!



Here is the D-B calibration chart showing the high resolution and accuracy you get with any D-B wavemeter.



Twelve models cover from 2.6 KMC to 140 KMC. Write for complete data in Bulletin D-B 715.

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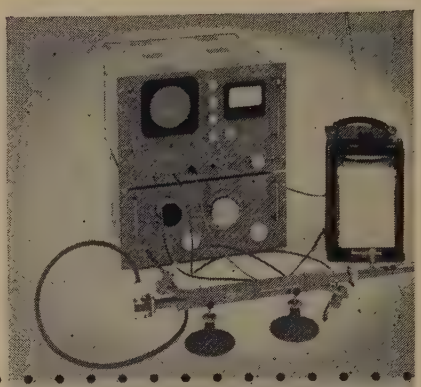
MICROWAVE INSTRUMENTS for the

- laboratory
- production line
- antenna pattern range

Direct-Reading VSWR

For instantaneous reading and recording of broadband VSWR characteristics, CTI VSWR Measuring Systems offer simplest operation and highest accuracy. Sweep-frequency systems have both meter and oscilloscope, output for recorder, and variable sweep-width.

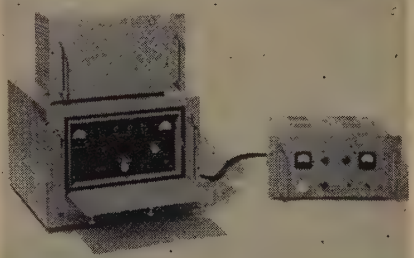
Model 160: Sweep-frequency, 8.4 to 12.0 kmc
Model 125: Sweep-frequency, 8.5 to 9.6 kmc
Model 110: Manually tuneable, 8.5 to 9.6 kmc
Calibrated Loads: Micrometer-type, 8.5 to 12 kmc
Bi-Directional Couplers: Dual couplers as used in above systems, 16-db coupling, over 45-db directivity, 0.1-db tracking accuracy.



Magnetron R-F Supplies

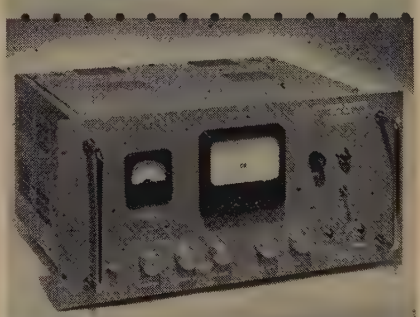
Ideal as tuneable r-f sources for antenna testing ranges, the Magnetron R-F Supplies feature remote control of frequency. PRF is 1,000 pps, adjustable. Exclusive: r-f sample for amplifier AGC. Units are available for S, C, X, K_u, and K_a bands.

Typical specifications:
Model 154A: 8500 to 9600 mc, 35 kw nom. pk. pwr.
Model 154B: 2845 to 2905 mc, 15 kw nom. pk. pwr.



Log-Linear Amplifier

With an input accommodating bolometers or crystal detectors, the Log-Linear Amplifier provides both a logarithmic d-c output, permitting the use of conventional recorders to plot db response on a linear scale, and a linear output for precise location of antenna half-power points. Includes AGC to correct for transmitted power changes.



Variable-Polarization Antennas

Polarization of these motor-driven antennas can be remotely controlled in 45° steps. Reflector size, frequency range, power ratings, and continuously variable control can be made to your requirements.

Engineers: Career opportunities are currently available at CTI

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DIVISION OF TEXTRON INC.
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Foremost in Automatic Testing

(*Continued from page 20*)

components and parts, under which manufacturers of power and transmitting electron tubes may reserve small fixed percentages for commercial orders. Heretofore the entire output of these tubes has been subject to the demands of rated (defense) orders.

H. B. McCoy, BDSA Administrator, said the supply situation in the industry permits the change.

Generally speaking, the change will permit manufacturers to reserve from 20 to 30 percent of their monthly production for commercial sales, depending on the item involved.

The change was effected by issuance of an amended Order M-17, to bring power and transmitting electron tubes within its scope. Prior to the change, Order M-17 covered only transistors, crystal diodes and electron tubes other than power and transmitting types.

Order M-17, which has been in effect since early in the Korean outbreak, is intended to provide equitable distribution of rated orders among manufacturers of the specified components, in order to achieve maximum production and to reduce to a minimum disruption of normal distribution.

In the amended order, the alternative base period on which a manufacturer's production level is to be computed has been brought up to date by changing it to the 6 calendar months preceding receipt of the rated order involved.

The amended Order M-17 was effective as of September 4.

● ● ●

G-R ENGINEERING DIRECTOR TO ATTEND HUNGARIAN ACADEMY OF SCIENCE MEETING

Donald B. Sinclair, chief engineer, vice president and a director of the General Radio Company, West Concord, Mass., attended a Colloquium on Microwave Communication sponsored by the Hungarian Academy of Sciences, held in Budapest, Hungary, November 10-13, 1959, as a representative of the IRE, of which he is past president, and is now a vice president and director.

Last year, Dr. Sinclair was a delegate to a similar meeting held in the USSR at which representatives from six Western nations and six Iron Curtain countries were invited guests.

Visits to the Iron Curtain countries during the past two years have been arranged on a reciprocal basis under the cultural and scientific exchange program agreed to by this and the Soviet governments. This visit, however, does not fall under the terms of the agreement and is one of the first to take place in recent years. Special permission is being issued by the State Department, since American passports are not ordinarily valid for travel in Hungary.

In furtherance of a possible resumption for more normal communications between our country and Hungary, an invitation to attend the Northeast Research and Engineering Meeting in Boston, November 17-19, has been extended to Hungarian electronics engineers.

Arnold Builds World's Largest Permanent Magnet...Used in Atomic Research

Vital Statistics on the Big Magnet

ere's how the world's champion permanent agnet weighed in: 1720 pounds of Alnico V the assembly . . . a keeper weighing 225 ounds . . . a total shipping weight of a tle over 2 tons.

Overall dimensions of the magnet assem-y, as illustrated at right, were 52½" x 36" 10", with a gap length of 16.5". The gap olume was 1584 cu. inches, and the density the center of the gap was 1100 gausses. Approximately 500,000 ampere turns were quired to magnetize the big unit, which as shipped magnetized and keepered. It was signed for use in auxiliary equipment serv-g a breeder reactor for the Argonne National boratory, operated by the University of icago for the U.S. Atomic Energy Com-ission. Actual service is in an electro-mag-tic pump for pumping fluid metals.

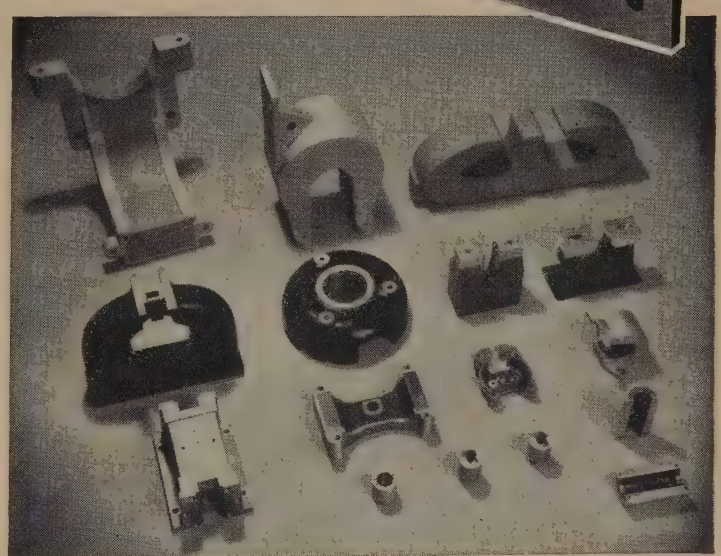
ital Suggestion for Your Requirements

The facilities and wealth of experience that oduced this world's largest permanent agnet are ready to bring you advantages, too. Arnold permanent magnets are available in types of Alnico and other magnet mate-ls, from large castings like the Argonne it to very small sintered parts weighing s than a gram. Many sizes and types of nico magnets are carried in stock for imme-ite delivery.

Special assemblies—such as rotors, travel-g wave tube and magnetron magnets, etc. may be supplied jacketed to facilitate ounting and give added protection to the agnet. Arnold also can supply large magnet emblies for mass spectrometer and other easuring applications, where a high degree stability and uniformity of field is required.

● Ask for a copy of Bulletin GC-106C, for re information on Arnold permanent mag-ts and other products, (tape cores, powder es, etc.) Write *The Arnold Engineering Com-ny, Main Office and Plant, Marengo, Illinois.*

ADDRESS DEPT MJ-911



Top: the world's largest permanent magnet, built by Arnold for Argonne Labs, was designed to supply a field of 1100 gausses in a gap of 16½ inches. Bottom: a typical group of the permanent magnet assemblies that Arnold supplies for rotors, traveling wave tube, wave guide and magnetron magnets, mass spectrometer and other measuring applications, etc.

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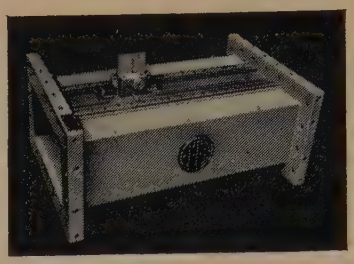
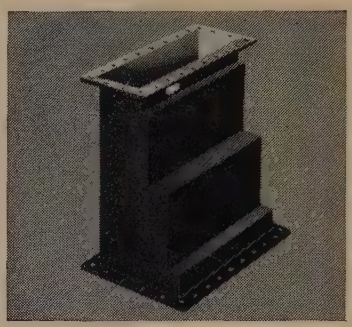
Also look to I-T-E to meet your special waveguide needs. I-T-E's experienced waveguide engineering group and highly specialized fabrication facilities will design and build waveguide to your specifications.

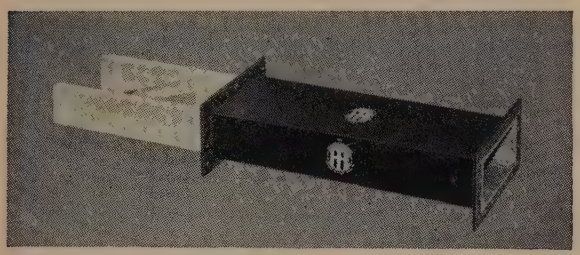
For additional information about I-T-E large waveguide—standard or special—write I-T-E Special Products Division.



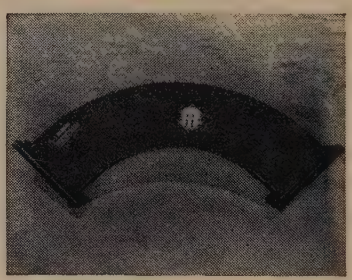
Slide-slug tuners



Stepped transformers

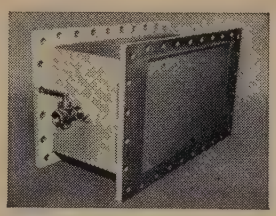


Terminations



Bends

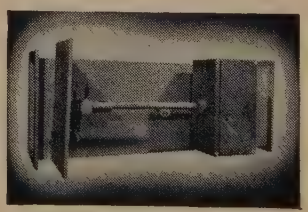
Waveguide to coax transition



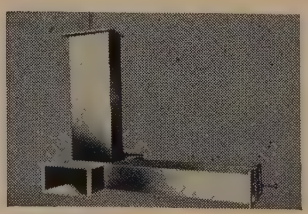
Gas barriers

Straight sections

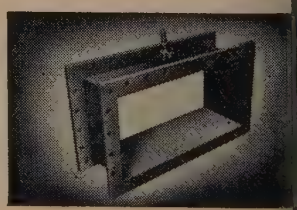
Slotted lines



Motorized short circuit sections



E-H plane tuners



Close-loop directional couplers

I-T-E CIRCUIT BREAKER COMPANY
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CIRCLE READER SERVICE CARD 19

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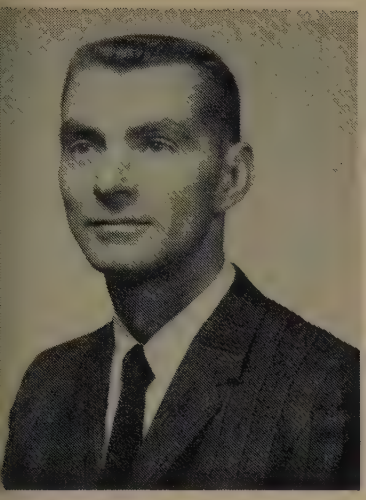

EDWARD S. HENSPERGER was born in New Brunswick, N.J. on December 12, 1925. After serving three and a half years in the Marine Corps in the South and Central Pacific during World War II, he entered Rutgers University in 1948, and received the degree of B.S. in electrical engineering in 1952.

In June, 1952, Mr. Hensperger joined Airtron, Inc., Linden, N.J. where he became engaged in the design and development of microwave components. In 1955, he left Airtron to become a senior design engineer at Stavid Engineering, Inc., Plainfield, N.J.

In 1956, Mr. Hensperger returned to Airtron as Section Engineer in charge of the advanced microwave design group. In this position, he took charge of the development of various ridge waveguide components, microwave filters, and other waveguide structures and systems.

In April, 1959, Mr. Hensperger joined Waveline, Inc., Caldwell, N.J., manufacturers of microwave test equipment, where he presently holds the position of Chief Engineer.

RTHUR L. WHITWELL was born in Bristol, England in 1922. His formal ıcation was directed towards a career in accountancy until the advent of World ar II. After six years of radar service in the Royal Navy, he was convinced that ɔermanent change to electronics engineering would offer opportunities for a ɾeer which would be satisfying in every respect.

He was awarded a B.Sc. degree from London University, and then corporate ɛmbership in the Institution of Electrical Engineers.

From 1947 to 1953, he was on the research staff of the Boulton Paul Aircraft ɯpany, including four years as head of electronics development department, d then followed a period of three years as chief of electronics, R. and D., with ɛntific instrument makers, Barr & Stroud Ltd. His work in these positions ɾered many aspects of military electronics, including flight instrumentation, ılogue computors, control systems and radar systems.

In 1956, he joined his present company, James Scott of Glasgow, as manager a new electronics division specializing in work of a development nature, t with manufacturing facilities.

NORMAN WILLIAMS was born in West Hartlepool, England on March 7th, 1928. He received an honours B.A. degree (in Natural Sciences) from Cambridge University, England in 1948, and an M.A. in 1952. In the same year he completed a postgraduate course at Edinburgh University and was awarded a diploma in electronics and radio.

After graduation and until early 1958, Mr. Williams was employed by Ferranti Limited, in a development laboratory engaged on new radar techniques. His work involved system engineering and assessment studies of new systems prior to their development. In February 1958, he joined the electronics division of James Scott & Company as the Chief Development Engineer and has been engaged in the development of a range of test gear. He has a number of patents pending principally in the field of industrial applied electronics.

Mr. Williams is an associate member of the Institution of Electrical Engineers.

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A NEW MICROWAVE TECHNIQUE FOR DETERMINING NOISE SPECTRA AT FREQUENCIES CLOSE TO THE CARRIER

Arthur L. Whitwell and Norman Williams
James Scott & Co., Ltd. Glasgow, Scotland

troduction

Progressive developments in the engineering and ap- ication of microwave systems call for increasingly ecise measuring apparatus and present day perform- ce specifications for microwave oscillators and allied vices prove no exception to this general rule.

For example, the purity of the CW output from an cillator will be limited by noise originating in the lve itself and random variations in the operating vels of power supplies to the valve, resulting in spuri- s AM and FM of the valve output. The spurious odulations are apparent as noise effects which impose nitations either directly or indirectly on the sensitivity d efficiency of a given system. In particular, in dop- er navigation and similar systems, the signal spectrum ay lie in the region close to the carrier frequency here the noise is likely to be most significant. In deter- ning the limiting sensitivity of a system with a narrow gnal spectrum — possibly measured in terms of tens hundreds of kilocycles — it is generally quite useless measure average noise power over a wide band of equencies since, as a rule, the noise spectrum is a rap- ly varying function of frequency and, apart from this, ere may be present unwanted components just as ob- tionable as random noise but arising from other uses. For example, signal breakthrough from various mponents of a system, including harmonics of the wer supply frequency. It follows that a resolution a few tens of cycles may be necessary.

The main requirements for a Spectrum Analyser for e particular purpose described are, therefore, as fol- ws:

The ability to distinguish between frequency and amplitude modulated noise and to present these spectra independently and with adequate isolation.

A narrow-band filter or "window" which may be located for the purpose of making noise power meas- urements at an accurately known frequency separa- tion from the carrier.

A high order of sensitivity.

These criteria have been met in the system which will w be described. In addition, tuning is not too critical d the sensitivity of the system can readily be checked, om time to time.

An R.F. input circuit and receiver is used in conjunc- n with a narrow band Spectrum Analyser with alterna- tive panoramic or manual display facilities. The RF unit comprises an input waveguide circuit followed by a two-channel superheterodyne receiver, the separate IF amplifiers being supplied from balanced mixers in order to materially reduce the effects of local oscillator noise. In one arrangement of the connecting circuits the receiver functions as a frequency discriminator,[1] providing linear conversion of an FM carrier signal to an amplitude modulated IF signal which is fed to a linear second detector. In this mode of use a high rejection of spurious carrier AM is achieved.

For the measurement of spurious carrier AM, only one IF channel is used in a straightforward superheterodyne conversion from RF to IF, followed by linear second detection.

The output from the second detector will be a video signal having an amplitude time characteristic corresponding to the amplitude modulated envelope of the RF carrier on the one hand, or to the frequency time deviations of the carrier on the other. In order to determine completely the nature of the spurious modulations, it is necessary to examine the spectrum of the video signal both visually and quantitatively and this can be done with the aid of the Spectrum Analyser, which forms an integral part of the Noise Measuring Equipment. A visual examination of the spectrum is generally necessary in order to enable the presence of lines corresponding to fixed frequency steady-state components to be identified and thus distinguished from random noise components.

A number of systems, designated Noise Measuring Equipments (NME) Type 123, have been designed for X and C-band frequency ranges, including several alternative arrangements for the video spectrum analyser. The performance data quoted in this article has been determined by measurements on an X-band equipment as shown in the accompanying illustration (see fig. 7.)

This equipment incorporates an RF milled block assembly, manufactured by Ferranti, Ltd., comprising the whole of the microwave bridge and mixer circuits. In addition to the saving in space that results, the use of the milled block technique ensures the highest possible stability in the microwave circuit and, in particular, reduces the possibility of the limiting sensitivity being strongly influenced by microphony in the waveguide circuit. Unfortunately, it is not always possible to make use of this technique as the extra cost and development time may prove prohibitive. The C-band equipments,

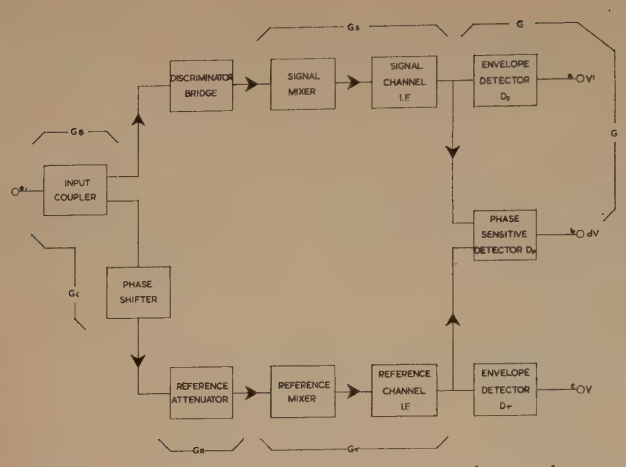

Figure 1. Schematic diagram of noise measuring equipment.

now in an advanced development stage, use standard waveguide components, but because of the generally larger dimensions, the dangers from microphony are much less.

RF System

Figure 1 shows a simplified block diagram of the system. The reference channel IF amplifier is fed from the source and the input to the signal channel is obtained from a frequency discriminator in the form of an RF bridge.

When the bridge is balanced, the output versus frequency response curve will be of the form shown in Figure 2 where the null occurs when the bridge cavity is tuned to the signal frequency. If a sinusoidal variation in source frequency occurs, the bridge output amplitude will vary in the manner shown in the diagram. It will be noted that a sign detector is required to enable the sense of the frequency deviation to be determined. It is, therefore, necessary to provide a second signal channel to derive a reference signal for the sign detector.

The sign detector, conventionally, comprises a hybrid transformer giving sum and difference outputs which

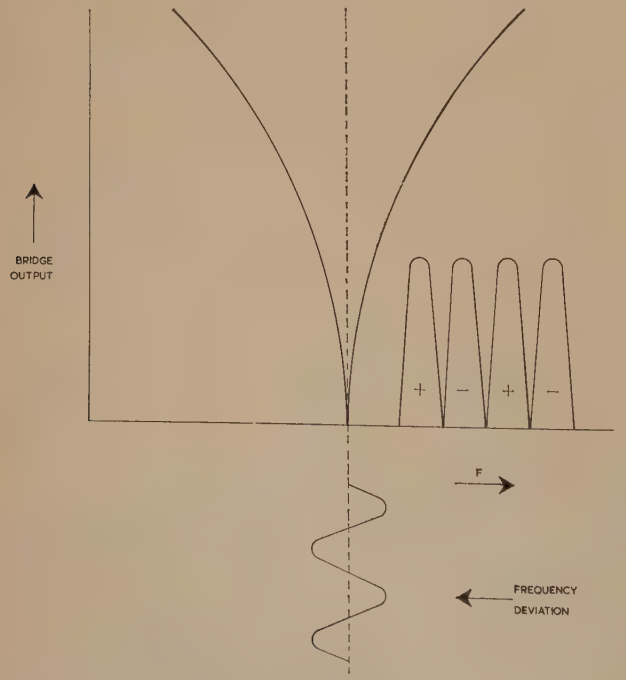

Figure 2. Frequency discriminator response.

are subsequently applied to linear detectors. Thus, th output from the second detector is an amplitude varyin voltage which follows the sense of the initial frequenc deviation and FM spectra can be plotted with a spectru analyser having a sufficiently high order of resolution.

The above description refers to ideal conditions an in practice the situation is complicated by imperfection in the performance of some of the components withou however, changing the basic method implied.

By removing the hybrid coupling at the input to th two channels, either of them may be used (with alte native second detectors), for comparing AM spectra o mean power. It is also possible to use the sign detecto with separate channel inputs in order to compare FI or PM relationships between RF signals from differe points on a transmission network.

A circuit diagram of a typical X-band system is show in Figure 3.

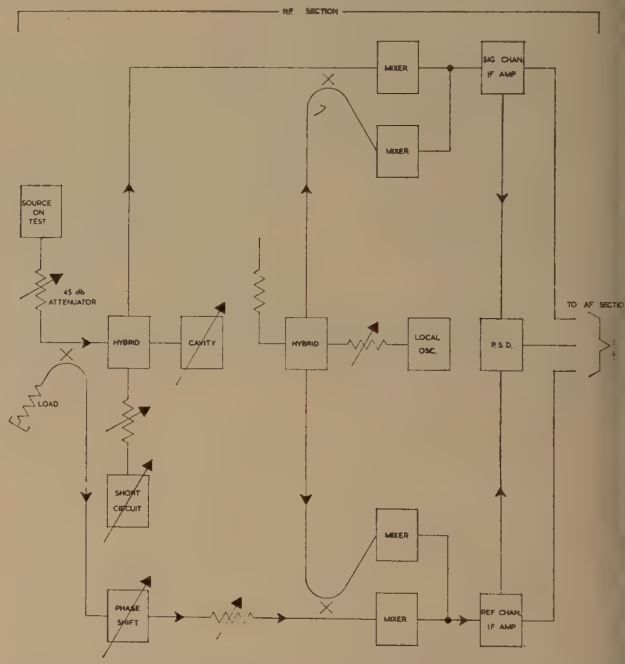

Figure 3. Circuit diagram of X-band RF system.

Output power from the tube on test is brought to th instrument and coupled via a 45 db variable attenuato to the waveguide assembly. The reference channel supplied via a 10 db coupler, phase shifter and atte uator and the output from the bridge hybrid goes the signal channel. The input power to the bridge split by a hybrid junction to arms terminated by th tuneable cavity in one arm and by a variable 20 d attenuator and short circuit in the other.

Balanced mixers are used in both channels to impro the noise factors of the receivers by minimizing th effects of local oscillator noise at the intermediate (fir conversion) frequency.

The cavity, which for the X-band systems has a unloaded Q of greater than 20,000, is matched to th waveguide so that it presents a VSWR of better tha 0.9 over a frequency range of approximately $\pm 10\%$ relative to the design centre frequency. The variab attenuator and adjustable short circuit together prese a variable impedance to the hybrid. This gives smoo control of the impedance on the balancing arm an enables a good bridge balance to be obtained for i perfect matching on the cavity arm.

Unfortunately, the match of the cavity is not the only mitation on bandwidth. The available sensitivity is mited primarily by the magnitude of the residual rrier power in the output from the bridge circuit and the inherent noise factor of the receivers. Therefore, e directivity and balance of the mixer hybrids must very good in order to obtain optimum sensitivity d, in practice, a balance of better than 0.1 db and rectivity of at least 23 db is specified and leads to practical bandwidth of about ± 4%. It will be appreciated that this bandwidth limitation only applies the case where the ultimate in performance is required and that measurements can be made over a mewhat wider bandwidth if a sacrifice in sensitivity tolerable.

It is convenient to mention here that the response the sign detector will be unaffected by variations in ference signal amplitude only if there is good phase acking between the two amplifiers over the IF bandidth. The RF phase shifter is used to control the hase relationship, and phase alignment over the IF nd is ensured by extremely careful, symmetrical conruction and alignment of the IF's and the sign dector hybrid.

It is the accuracy of phase alignment between the vo channels together with the magnitude of the M/AM conversion factor which determine the extent which discrimination against residual signal AM curs when FM measurements are made.

M to AM Conversion Sensitivity

The theory of FM measurement, including FM to AM nversion sensitivity and limiting sensitivity can be und quite simply from first principles. It is conenient to use equivalent lumped circuit parameter ncepts in deriving the characteristic formulae for the icrowave discriminator. The result is a simple relaonship between frequency deviation and voltage levels hich are measured at the output from the R.F. unit.

It can be shown that the measurement system is self-ecking in that once an initial calibration has been ade to determine the values of certain constants, subquent adjustment, to set up the required sensitivity, n be made using only a simple low-power CW test urce which need not be modulated. This is an imortant point since it is not easy to set up sources with curately known degrees of modulation at the levels ith which we are concerned in this work. Quite apart om the time-saving aspect, there is a high degree of rtainty about the accuracy with which measurements ill be made.

Consider the equivalent circuit of the RF receiver Figure 1.

ne parameters of interest are:

- $_s$ the gain of the signal channel from the crystal mixer to the input of the envelope detector D_s.
- the gain from the input of D_S to the output of the phase sensitive detector D_p.
- $_r$ the gain of the reference channel from the crystal mixer to the input of the envelope detector D_r.
- $_B$ the "gain" across the input coupler in the series branch.
- $_c$ the "gain" across the input coupler in the transfer branch.
- $_A$ the "gain" across the reference attenuator and phase shifter.

e_i the RMS RF voltage at the input to the receiver.
e_i^1 the RMS RF voltage at the input to the bridge.
e_o the RMS RF voltage at the input to the signal channel mixer.
e_r the RMS RF voltage at the input to the reference channel mixer.
dV the change in voltage measured at the output from the phase sensitive detector D_p, for a change df in RF frequency.
V the measured output from the reference envelope detector.
f_o carrier frequency
d_f a small deviation relative to the carrier frequency f_o.
f a modulation frequency.
Q_e the unloaded Q of the FM discriminator cavity.
n the ratio of the input e_i to the reference channel signal level e_r.

The discriminator is essentially a balanced microwave bridge and is sketched schematically in Figure 4. The bridge arms comprise matched input and output waveguide branches a and d, arm b which is coupled to a high Q cavity and a fourth arm, c, which comprises a variable 20 db attenuator and a tuneable short circuit.

The components in the "balance" arm, c, may be adjusted so as to present a variable impedance to the hybrid in order to compensate for any small mismatch which may exist between the cavity and arm b at resonance, and so maintain an equal division of power between b and c and also ensure that reflections arising in these junctions as a result of the mismatch are self-cancelling in the output arm d.

The cavity is tuned to the carrier frequency f_c and the balancing components are adjusted for a minimum output e_o. In order to find out what happens when the carrier frequency is altered by a small amount, it is convenient to consider a lumped parameter equivalent circuit for the cavity arm.

At frequencies close to resonance, a cavity can be represented by a simple LC circuit[2] (see Figure 5) whose impedance for high Q is quite accurately represented by the equation

$$Z = Z_o \left(1 - 2j \frac{df}{f_o} \cdot Q_c\right) \qquad (1)$$

where $Z_o = \frac{L}{RC}$,

the impedance at resonance, which is of course purely

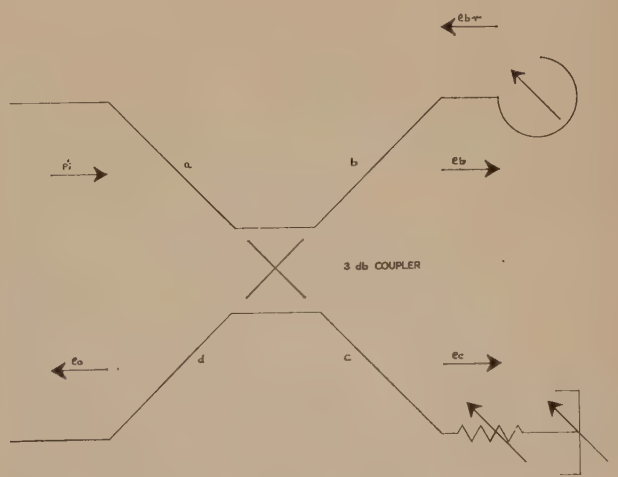

Figure 4. Frequency Discriminator bridge.

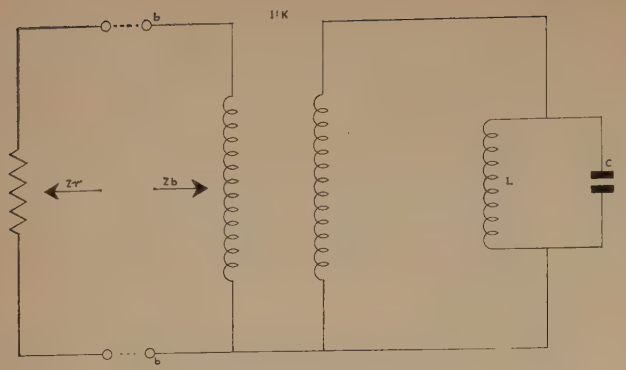

Figure 5. Equivalent LC circuit of cavity arm.

resistive in the case of the simple, approximate model chosen.

Let Z_r be the characteristic impedance of the guide, then for a match at resonance $Z_r = Z_o/K^2$ and, in general, the impedance of the cavity is normalized to the guide impedance. The cavity impedance as seen looking into the guide branch b is, therefore,

$$Z_b = Z_r \left(1 - 2j \frac{df}{f_o} \cdot Q_c\right) \tag{2}$$

If e_b is the magnitude of the incoming signal voltage, and e_{br} the reflected voltage arising from the small mismatch represented by equation (2), then:

$$\left|\frac{e_{br}}{e_b}\right| = \left|\frac{Z_r - Z_b}{Z_r + Z_b}\right| = \frac{d_f}{f_o} \cdot Q_c \tag{3}$$

Now, from the properties of a directional coupler or magic tee:

$$e_b = e_i^1/2^{\frac{1}{2}} = e_i G_B/2^{\frac{1}{2}} \text{ and } e_o = e_{br}/2^{\frac{1}{2}}$$

$$\therefore \frac{2e_o}{G_B e_i} = \frac{d_f}{f_o} \cdot Q_c \tag{4}$$

Also, by definition, $n = e_i/e_r$

$$\therefore \frac{d_f}{f_o} = \frac{2}{G_B Q_c} \cdot \frac{e_o}{e_i} = \frac{2}{G_B Q_c} \cdot \frac{e_o}{n e_r} \tag{5}$$

$$\text{Now, } e_o = dV/G \cdot G_s \text{ and } e_r = V/G_r \tag{6}$$

$$\therefore \frac{d_f}{f_o} = \frac{2}{nQ_c} \cdot \frac{dV}{G \cdot G_s \cdot G_B} \cdot \frac{G_r}{V}$$

$$\therefore d_f = \frac{dV}{V} \cdot \left\{\frac{2f_o}{\frac{G \cdot G_s \cdot G_B \cdot n \cdot Q_c}{G_r}}\right\} \tag{7}$$

It is shown later that the term in the brackets in equation (7) can be accurately determined and that once found for a particular frequency, f_o, the system can be readily adjusted to maintain constant sensitivity thereafter.

This equation is derived from steady-state considerations, but is equally applicable where d_f and consequently dV are functions of time. The varying output from the phase sensitive detector is examined by the video spectrum analyser which measures the RMS magnitude of the components of (dV) which lie in a predetermined narrow band of frequencies. On the other hand, the level V measured at the output from the reference channel represents the peak carrier amplitude and it is the ratio between these two quantities which is defined as the "signal-to-noise ratio."

Equation (7) may be written:

$$\frac{dv}{V} = \frac{d_f}{f_o} \left(G \cdot \frac{G_s}{G_r} \cdot nG_B Q_L\right) \tag{8}$$

where Q_L is the loaded Q of the matched cavity and the conversion sensitivity is proportional to the magnitude of the term in the bracket. The factor $G.G_s/G_r$ approximates unity for maximum receiver sensitivity and G_B is a small loss factor which does not exceed 1 db. It follows that only the product $n \cdot Q_L$ is significant in determining sensitivity.

The maximum possible value of Q_L is generally determined, not so much by practical engineering limitations as by the required range of linear FM to AM conversion. If f is the maximum modulation frequency then the required bandwidth for linear operation of the discriminator is 2f so long as the ratio df/f is less than 0.4.[3] Also the effects of imperfect bridge balance and relatively slow frequency drift in the oscillator under test during the course of a measurement must be considered and the linear range increased accordingly. For example, a modulation range of 120 Kcs requires a minimum 3 db bandwidth of about 600 Kcs in practice and the maximum practicable cavity Q_L is limited to rather less than 20,000.

Having determined the permissible magnitude of Q in a particular case, it only remains to consider the remaining factor "n." This, it will be remembered, is the ratio of the test oscillator voltage at the input of the system to the voltage which would be measured at the input to the reference channel mixer. The maximum signal power level at this point, as determined by the power handling capacity of crystals, is about 400 μW so the first limitation is the power available from the test oscillator and the next arises from the operation of the discriminator in the signal channel. The residual signal power level at the input to the signal channel mixers has to be about 10 db's down on the signal power at the reference channel mixer in order to ensure linear operation of the sign detector at the output from the IF's; this level will be about 40 μW. It follows, therefore, that the maximum permissible value of the ratio "n" will be determined entirely by the degree of carrier cancellation obtained in the discriminator, providing adequate power is available from the source.

The effective carrier cancellation obtainable will depend not only on the degree of balance provided by manually tuning the bridge, but also on the stability of the frequency of the test source and, in practice, it has been found that maximum values of "n" varying from 30 to 40 db are practicable, depending on the quality of the tube under test.

Referring again to equation (8), the voltage V at the output from the reference envelope detector is nominally 4 volts. Assuming an input power of 400 mW and Q_L equal to 15,000 and an "n" factor equivalent to 30 db, the frequency deviation sensitivity at the output of the phase sensitive detector may be calculated to be approximately 270 microvolts/c.p.s. deviation. This sensitivity may be adjusted over fairly wide limits by increasing or decreasing the input power to the bridge.

Limiting Sensitivity

The limit of sensitivity to be expected from the equipment may be deduced as follows:

The available thermal noise power in a one cycle bandwidth[4] at room temperature is —204 dbw and a typical noise figure for each receiver is 13 db. Therefore, for a 100 cps noise bandwidth the available noise power at the mixers is — (204-20-13) = — 171 dbw (9)

Now, the signal input power level at the mixer, which is required to give 4 volts output at the reference envelope detector, is approximately 400 microwatts, i.e. -33 dbw (10)

So that the ratio of signal input to system noise is -137 dbs, (i.e. equation (9) — equation (10)), and this figure represents the theoretical limiting sensitivity of the equipment under the conditions specified.

Measurements of AM modulations corresponding to signal-to-noise ratios approaching — 137 dbs may, therefore, be made on the reference channel or, indeed, on the signal channel, if the bridge is detuned. This sensitivity is not exceptional but adequate and it should be remembered that the primary purpose of the system is the measurement of FM.

The limiting FM sensitivity is obtained when the measured RMS noise voltage level at the output of the sign detector is — 137 db relative to 4 volts. Since a typical figure for the frequency deviation sensitivity is 70 microvolts per cps deviation, it follows that the system is limiting for a deviation of 0.003 cps approximately.

The results quoted are optimistic, since the preceding discussions are based on several approximations and assumptions. In particular, the effects of combined FM and AM have not been considered. In this connection, it may be observed that the use of the sign detector enables some 30 dbs of rejection of residual AM on the reference channel to be obtained. Also, while in the bridge circuit, FM is converted to AM at the output consider the relation of equation (3) operating on a pair of equally spaced sidebands), conversely AM is converted to FM and the sign detector discriminates against (converted) AM when the reference phase is correctly adjusted.

In practice, it has been found possible to measure signal-to-noise ratios of the order of 133-135 dbs in both AM and FM on X-band sources. The corresponding limiting sensitivity in terms of frequency is approximately 0.01 c/s deviation in a 70 cps band for FM and this sensitivity can be achieved in the presence of significant, but not over-riding, AM noise.

Calibration

In order to use the equipment, it is necessary to have calibration data for the cavity and reference attenuator and to know the transmission loss/frequency characteristics corresponding to the parameters G_A and G_B. These can readily be determined by normal laboratory measurement techniques. With this data, the following system checks can be rapidly executed, when necessary. All that is needed is an external test source capable of providing 1-500 mw of RF power, and "quiet" with respect to AM noise and stable in frequency.

(a) *Relative Gain Factor* (G_s/G_w).

With the cavity detuned, the attenuation of signal voltage over the discriminator network will be 6 dbs, and the loss in the series branch of the input coupler, corresponding to factor G_B in equation (8), may be assumed to be approximately ½ db. Assuming the transfer branch attenuation of the input coupler is 10 db and the phase shifter introduces negligible loss, the difference in voltage levels e_o and e_r (Figure 1) will correspond to 10-6.5 = 3.5 db.

The signal levels V^1 and V at the signal and reference envelope detectors for equal IF and mixer gains should, therefore, be in the ratio of 1.5:1, and any significant departure from this figure indicates the gain difference between the two channels and the relative gain ratio G_s/G_r may be calculated.

(b) *Gain from signal envelope detector to sign detector output* (G)

The output voltage levels from the signal envelope detector and from the phase sensitive detector are monitored for a suitable level of input voltage and with the reference phase shifter adjusted to give maximum output. The ratio between these outputs then gives the magnitude of G.

Referring again to equation (8), it may be noted that the parameters Q_L, G_B and n are all determined, or determinable, from the initial calibration data and it is only necessary to carry out the tests (a) and (b) above in order to check the sensitivity equation.

The limiting sensitivity may be determined at the same time and with the same test source, providing the noise from the source is at a sufficiently low level.

Since, in practice, the equipment will normally be used for measurements on high quality oscillators, the oscillator under test will usually have an adequate performance and, in such a case, the system may be described as self-checking in that no external sources or test gears are required.

Video Spectrum Analyser

The video spectrum analyser used with the NME is a self-contained instrument. A schematic diagram of this unit is shown in Figure 6 with data appropriate to a 90 Kcs modulation range.

The three available outputs from the RF receiver are taken to a selector switch at the input to the video spectrum analyser. Whether or not the investigation interest lies in FM or AM spectra, the outputs from the demodulators or sign detector are video signals, and their RMS values may be determined immediately by means of monitoring detector current meters.

In many cases, however, it will be necessary to examine the spectra of the converted signals and this function is achieved by the spectrum analyser. A schematic diagram of this unit is shown in Figure 4.

The video signal is first amplified and then fed to a wide-band mixer, the reference carrier into the mixer being derived from a manually tuned calibrated oscillator with a tuning range from 101 to 190 Kcs, but with the dial calibrated in terms of the difference frequency, i.e. 1 to 90 Kcs. Sum and difference frequency components are generated in the mixer and appear as output signals which are coupled into a frequency selective amplifier centered on 100 Kcs. Thus, only difference signals having frequency components within the pass-band of the tuned amplifier (which is arranged for sharp cut-off beyond its range) are transmitted

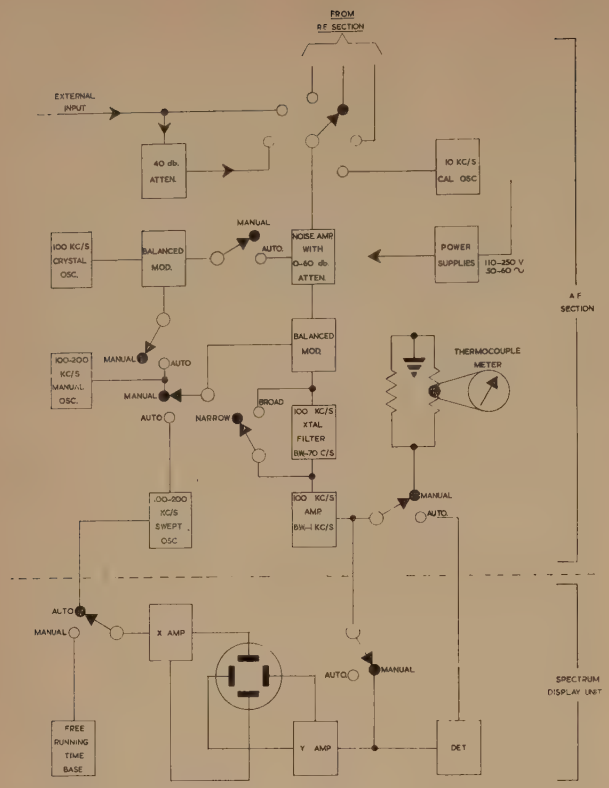

Figure 6. Schematic diagram of video spectrum analyzer.

through to the final stages and measuring circuits of the equipment. For quantitative work, the output power in either a 70 cps or a 1 kcs band of frequencies is determined by means of a thermocouple microammeter and the manual oscillator can be tuned through its range. Noise power measurements can then be made as frequently as desired. In order to permit qualitative visual examination of the spectrum, provision is made to switch out the manually tracked local oscillator of the spectrum analyser and substitute a sweeping oscillator covering the required difference frequencies in two ranges, 1-7 Kcs and 1-90 Kcs. The local oscillator sweep voltage is used to derive the time base of an oscilloscope employed for viewing the spectrum.

On the 1-7 Kcs range, the 70 cps band-pass amplifier is used, but the bandwidth is increased to 1 kcs for automatic sweep on the 1-90 Kcs range in order to produce an easily read spectrum curve.

The sweep rate is necessarily rather low in order to avoid distortion and loss of signal through the narrow-band amplifier and it is, therefore, necessary to incorporate a medium or long persistance C.R.T. in the display unit.

Calibration of the time base is effected by a marker trace signal derived from the manual oscillator and coupled into the noise amplifier before the mixer circuit. A crystal controlled local oscillator is used as a reference in the marker frequency mixer. This method of deriving a marker signal has the particular advantage that once any line on the display has been "pointed" by a marker blip, very little further adjustment of oscillator frequency is necessary to peak the meter reading on switching to "manual," since the same oscillator output is employed.

Acknowledgments

The work described was sponsored by the Royal Radi Establishment of the Ministry of Supply, and the autho had free access to a number of unpublished R.R.E. r ports and papers. In particular, discussions with S. Marsh, J. D. Clare and S. A. Drage of R.R.E., wh evolved the frequency discriminator and constructed th first experimental models, have been most helpful.

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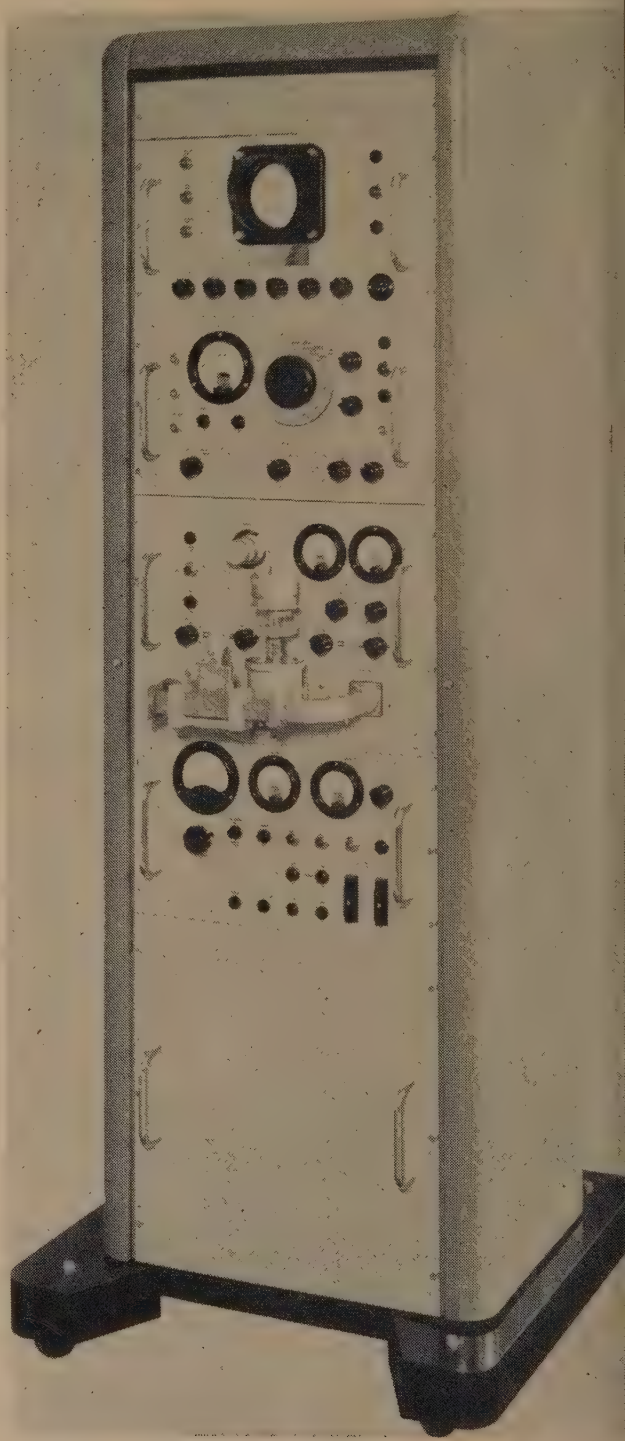

Figure 7. Scott noise measuring equipment type 123B.

AMPLITUDE—AND PHASE—SENSING MONOPULSE SYSTEM PARAMETERS

An analysis of amplitude- and phase-sensing sum-and-difference monopulse systems is made in an attempt to specify the effects certain parameters have on system performance. The effects of pre-comparator voltage unbalance, phase shifts and post-comparator phase shifts are shown and compared for each type of sensing system. Since the basic difference between a phase-sensing and amplitude- sensing monopulse system lies in the antenna configuration, major attention is given to the antenna and the microwave assembly which produces the monopulse additions and subtractions. To complete the evaluation, the parameters which affect the receiving equipment performance have also been developed. Equations describing the performance of the systems have been derived and system evaluation curves have been plotted using these equations.

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PART II

PHASE-SENSING MONOPULSE SYSTEM

Antenna Parameters

Figure 1 shows the antenna configuration of a phase-sensing system and the general situation of the reflected radar energy returning at an angle θ with respect to the plane of the antenna apertures. It is assumed here that the phase centers of the antennae are at the same point as the geometrical centers. A signal arriving at antenna A will be delayed from that arriving at antenna B due to the distance S. From the diagram one can see that $S = d \sin \theta$.

Letting $\phi =$ phase delay due to this distance S we have

$$\phi = \frac{2\pi s}{\lambda} = \frac{-2\pi d \sin\theta}{\lambda} \qquad (10)$$

where λ is the wavelength of the carrier frequency. The antenna voltages may be given as follows:

$$A = K_1 \sin(\omega_c t + \phi)$$

and (11)

$$B = K_1 \sin(\omega_c t)$$

where ω_c is the angular velocity of the carrier and K_1 is an arbitrary value which is related to the transmitted power, range, backscattering conditions and antenna parameters.

For the difference channel (A-B) we have:

$$E_D = K_1 [\sin(\omega_c t + \phi) - \sin(\omega_c t)] \qquad (12)$$

The resultant output, E_D, is then composed of the subtraction of two voltages of the same frequency but of changing phase. This expression can be rewritten as a single resultant voltage and phase angle as follows:

$$E_D = K_D \sin(\omega_c t + \alpha_D)$$

where

$$K_D = K_1 \sqrt{(\cos\phi - 1)^2 + (\sin\phi)^2} = 2K_1 \sin \tfrac{1}{2}\phi \qquad (13)$$

and

$$\alpha_D = T_{AN}^{-1}\left[\frac{\sin\phi}{\cos\phi - 1}\right]$$

The phase angle expression can be simplified further and may be expressed in two ways:

$$\alpha_D = \frac{\pi}{2} + \tfrac{1}{2}\phi \qquad 0° < \phi < 360°$$

or

$$\alpha_D = \frac{\pi}{2} + \tfrac{1}{2}\phi \qquad 0° < \phi < +180°$$

$$\alpha_D = \frac{3\pi}{2} + \tfrac{1}{2}\phi \qquad 0° > \phi > -180°$$

The second expression will become useful when this phase angle is compared with the sum signal later on.

Similarly for the *sum channel* we have

$$E_S = K_1 [\sin(\omega_c t) + \sin(\omega_c t + \phi)] \text{ or } E_S = K_S \sin(\omega_c t + \alpha_S) \qquad (14)$$

where

$$K_S = K_1 \sqrt{(1 + \cos\phi)^2 + (\sin\phi)^2} = 2K_1 \cos \tfrac{1}{2}\phi \qquad (15)$$

and

$$\alpha_S = T_{AN}^{-1}\left(\frac{\sin\phi}{1 + \cos\phi}\right)$$

The sum channel phase expression can also be simplified and may be expressed as

$$\alpha_S = \tfrac{1}{2}\phi \qquad 180° > \phi > -180°$$

Using the above derived equations, the relative amplitude of the sum and difference channels, as a function of ϕ, are plotted in Figure 11.

If the magnitude of ϕ is allowed to become larger than $\pm 180°$, the even order functions shown will repeat giving rise to ambiguous nulls. In view of the fact that the null is used to define the antenna bore-

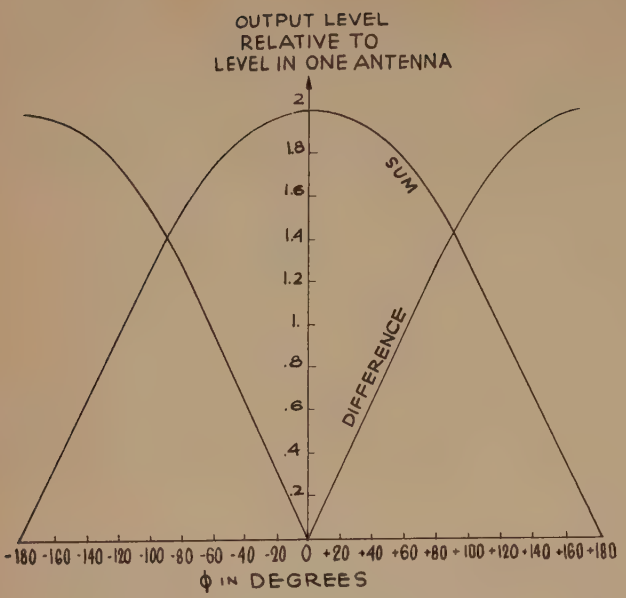


Figure 11. Signal Amplitude of sum and difference channels in a phase-sensing monopulse system.

sight, the system would then be inoperative unless these ambiguities are resolved.

The method for eliminating the ambiguities in a phase-sensing monopulse system is by limiting the angles of signal arrival θ. This is accomplished by restricting the antenna beamwidth so that $\phi \left(\frac{2\pi d}{\lambda} \sin\theta \right)$ is within $\pm 180°$. In both sensing systems similarly shaped sum and difference patterns result from the comparator.

Comparison of the phase angles of the sum and difference signals yields the following results:

$$\alpha_S - \alpha_D = \tfrac{1}{2}\phi - \left[\frac{\pi}{2} + \tfrac{1}{2}\phi \right] = -\frac{\pi}{2} \qquad 0° < \phi < +180°$$

$$\alpha_S - \alpha_D = \tfrac{1}{2}\phi - \left[\frac{3}{2}\pi + \tfrac{1}{2}\phi \right] = -\frac{3}{2}\pi \qquad 0° > \phi > -180° \qquad (16)$$

These equations have been plotted in Figure 12, where it can be seen that for $\gamma \doteq 0°$, an instantaneous phase reversal occurs at the boresight or null, $\theta \doteq 0°$ or $\phi = 0°$. It will be remembered that this was also true for the amplitude-sensing system.

Phase Shift Effects

However, if we now assume that a phase delay, γ, occurs in the antenna feed, B, the corresponding equations change as follows:

$$E_{S1} = K_{S1} \sin \left[\omega_c t + T_{AN}^{-1} \frac{\sin\phi - \sin\gamma}{\cos\phi + \cos\gamma} \right]$$

One change lies in the value of α_S which is now

$$\alpha_{S1} = T_{AN}^{-1} \left[\frac{\sin\phi - \sin\gamma}{\cos\phi + \cos\gamma} \right]$$

or $\alpha_{S1} = \tfrac{1}{2}(\phi - \gamma) \qquad 180° > \phi + \gamma > -180°$

Similarly for the difference channel,

$$\alpha_{D1} = T_{AN}^{-1} \frac{\sin\phi + \sin\gamma}{\cos\phi - \cos\gamma} \text{ or}$$

$$\alpha_{D1} = \frac{\pi}{2} - \tfrac{1}{2}(\gamma - \phi) \qquad 0° < \gamma + \phi < +18$$

$$\alpha_{D1} = \frac{3\pi}{2} - \tfrac{1}{2}(\gamma - \phi) \qquad 0° > \gamma + \phi > -18$$

(1

The phase difference between the sum and differen channels $\alpha_{S1} - \alpha_{D1}$ will equal the following expressio

$$\alpha_{S1} - \alpha_{D1} = -\frac{\pi}{2} \qquad 0° < \gamma + \phi < +18$$

$$\alpha_{S1} - \alpha_{D1} = -\frac{3}{2}\pi \qquad 0° > \gamma + \phi > -180°$$

(1

The two conditions, before and after the null, a similar to those calculated before, except that the pha reversal occurs when $\phi = -\gamma$ and not when $\phi =$ This would indicate a change of boresight if a true pha detector were used.

Now, returning to the general sum and difference eq tions and solving for the amplitude expression we fi for the sum amplitude

$$K_{S1} = K_1 \sqrt{(\cos\gamma + \cos\phi)^2 + (\sin\phi - \sin\gamma} = 2K_1 \cos \tfrac{1}{2}(\gamma + \phi) \qquad (1$$

and for the difference amplitude

$$K_{D1} = K_1 \sqrt{(\sin\phi + \sin\gamma)^2 + (\cos\phi - \cos\gamma} = 2K_1 \sin \tfrac{1}{2}(\gamma + \phi) \qquad (2$$

In order to find when $K_{D1} = 0$, i.e. a null, we c set equation 20 equal to zero and solve for ϕ.

$$2K_1 \sin \tfrac{1}{2}(\gamma + \phi) = 0$$

$$\sin \tfrac{1}{2}(\gamma + \phi) = 0$$

$$\phi = -\gamma \qquad (2$$

Since $\phi = -\gamma$ at the null, it can be seen that the a plitude null advances the same amount as the phase versal point advances for the same phase delay γ.

The advance of an amplitude null has been shown Figure 13 for $\gamma = +10°$. Likewise, it can be se in Figure 12, how the phase reversal point advan because of a pre-comparator phase shift of $\gamma = +1$

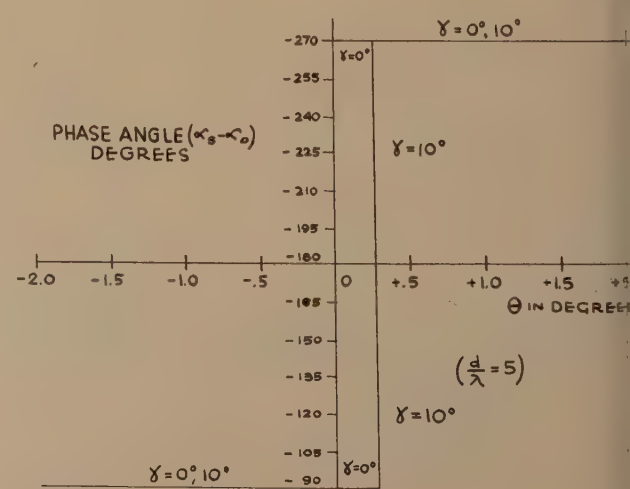


Figure 12. Phase difference vs. angle (phase-sensing syste

hus it may be seen that the amount of null or phase reersal shift for a given phase shift depends on the alue. $\frac{2\pi d}{\lambda}$.

o indicate the effect the $\frac{d}{\lambda}$ ratio has on the amount ne null and phase reversal will shift, a plot for various alues of $\frac{d}{\lambda}$ is shown in Figure 14. Observe that the reater the value of $\frac{d}{\lambda}$ the less the shift. This demonrates that in designing a phase-sensing system the pacing of the antennas and the wavelength of the carer are important parameters in determining the errors hat will be encountered in the operation of the system.

oltage Unbalance Effects

Again consider the case of some attenuation in one nannel, A or B. For the sake of argument, let the oltage in the A channel be reduced by a factor $1 < 1$. he corresponding equations change as follows: For ne difference channel

$$E_{D2} = K_{D2} \sin\left[\omega_c t + T_{AN}^{-1}\left(\frac{\sin\phi}{\cos\phi - 1}\right)\right] \quad (22)$$

here

$$K_{D2} = K_1\sqrt{(\cos\phi - 1)^2 + (\sin\phi)^2}$$

nd

$$\alpha_{D2} = T_{AN}^{-1}\left(\frac{\sin\phi}{\cos\phi - 1}\right)$$

milarly for the sum channel voltage under these conions we find

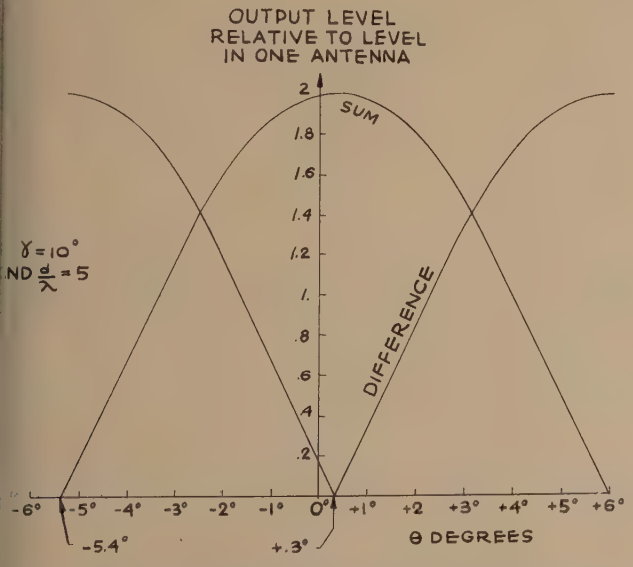
$$E_{S2} = K_{S2} \sin\left[\omega_c t + T_{AN}^{-1}\left(\frac{\sin\phi}{1 + \cos\phi}\right)\right]$$

here

$$K_{S2} = K_1\sqrt{(1 + \cos\phi)^2 + (\sin\phi)^2}$$

nd

$$\alpha_{S2} = T_{AN}^{-1}\frac{\sin\phi}{1 + \cos\phi} \quad (23)$$



igure 13. Signal amplitude of sum and difference channels in a phase-sensing monopulse system with pre-comparator phase shift.

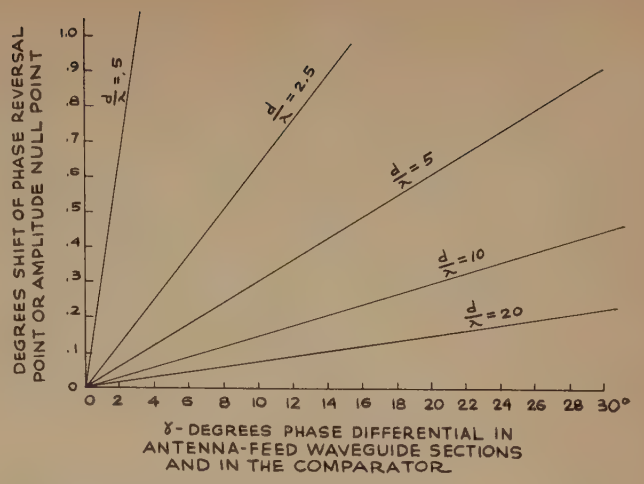

DEGREES SHIFT OF PHASE REVERSAL POINT OR AMPLITUDE NULL POINT
d/λ=.5
d/λ=2.5
d/λ=5
d/λ=10
d/λ=20
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30°
γ- DEGREES PHASE DIFFERENTIAL IN ANTENNA-FEED WAVEGUIDE SECTIONS AND IN THE COMPARATOR

Figure 14. Null or phase reversal shift vs. pre-comparator phase shift (phase-sensing monopulse system.)

A plot of these equations for amplitude effects are shown in Figure 15 for voltage unbalances of 1.0 db, 0.4 db and 0.1 db. The sum channel amplitude does not change over this range, but it can be seen how the difference null "fills in."

When these nulls "fill in," the resolution of the radar system declines. A representative plot of null depth vs voltage unbalance is shown in Figure 16. Since the actual null depth varies with the antenna shaping parameters, this curve is only indicative of the change in null depth with a change in voltage unbalance.

The resultant phase angle ($\alpha_{S2} - \alpha_{D2}$) has been plotted in Figure 17 for various voltage unbalances. Instead of a sharp phase transition at $\phi = 0°$, it becomes more gradual as the voltage unbalance is increased. This is similar to the amplitude-sensing system which had a pre-comparator phase shift. Here also post-comparator phase shifts will cause a reversal in phase at a point other than $\phi = 0°$ which would indicate an error in boresight. This results in the same effect shown in Figure 8 for the amplitude sensing system.

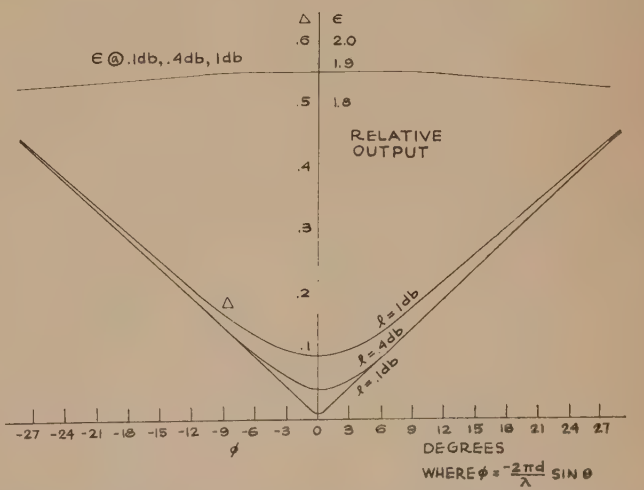


Figure 15. Amplitude of sum and difference channels with voltage unbalance (phase-sensing monopulse system.)

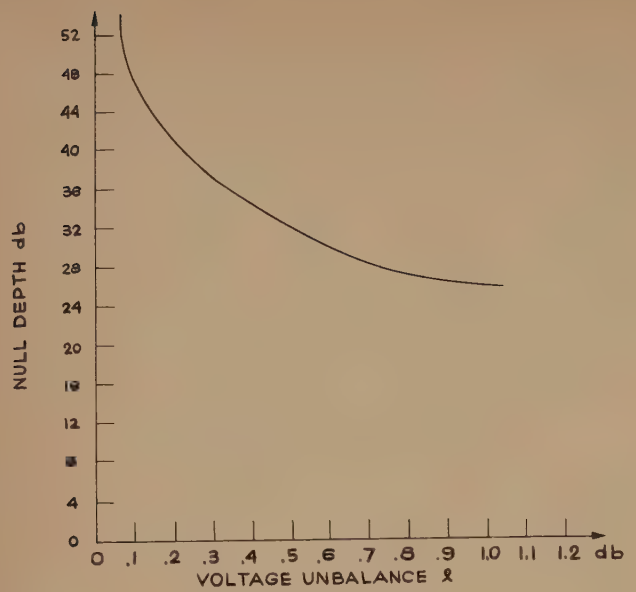


Figure 16. Null depth vs. pre-comparator voltage unbalance (phase-sensing system).

RECEIVING EQUIPMENT

Phase Detector

Both amplitude and phase information from either monopulse system can be utilized in a phase-sensitive amplitude detector shown in Figure 18. The detector's output voltage can be described by the following equation:

$E_0 = \sqrt{|E_S||E_D|}\cos(\alpha_S - \alpha_D + \alpha_K)$ where α_K is any constant phase shift after the comparator, E_0 is the output voltage of the detector, $|E_S|$ is the magnitude of the sum channel signal and $|E_D|$ is the magnitude of the difference channel signal. It was shown in the amplitude section that $(\alpha_S - \alpha_D)$ is either 0 or $-\pi$ and if $\alpha_K = 0$, the term $\cos(\alpha_S - \alpha_D + \alpha_K)$ is either $+1$ or -1. This also holds true in a phase system if a constant phase shift of $\frac{\pi}{2}$ is added to the expression, $(\alpha_S - \alpha_D)$. The magnitude of the detector output depends on $|E_S|$ and $|E_D|$ and changes sense when the phase of the two signals reverse. Usually $|E_S|$ is made larger than $|E_D|$ and supplies the necessary phase reference. Thus the output of the phase-sensitive amplitude detector will be mainly a function of the amplitude characteristic of $|E_D|$. This output is commonly referred to as the "S" curve.

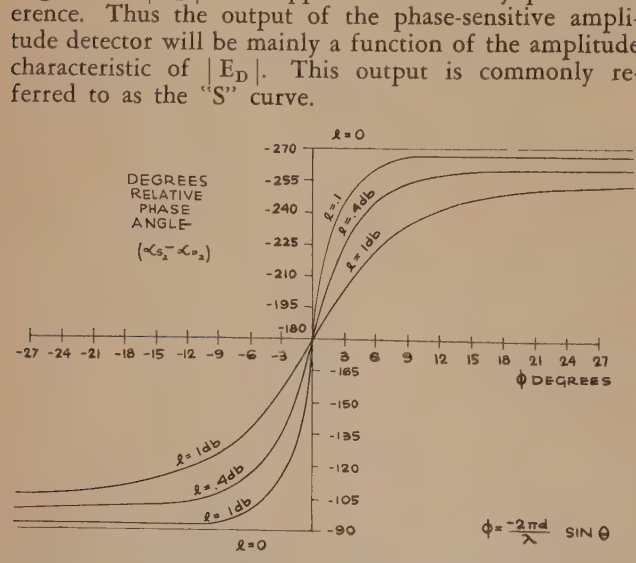


Figure 17. Phase difference vs. angle for phase system with voltage unbalance.

The slope of the "S" curve around the crossover poin depends upon many factors.

1. The range
2. The receiver gain
3. The backscattering area of the target or ground
4. STC effectiveness
5. Other receiver and transmitter constants

If $(\alpha_S - \alpha_D + \alpha_K)$ is not 0° or − 180° due to a additional phase constant, $\alpha_K \neq 0$, added to it, th cosine term will not equal ± 1 but plus or minus som smaller value and the sensitivity of the detector will b reduced. This will reduce the signal to noise ratio o the receiver, and will cause the second order chang in the crossover point of the "S" curve as described i Figure 8. Calculations of receiver desensitization as function of post comparator phase shift, α_K, have bee plotted in Figure 19.

A point worth noting here is the output of the phas sensitive amplitude detector

$$\sqrt{|E_S||E_D|}\cos\left(\alpha_S - \alpha_D + \frac{\pi}{2}\right)$$ for th

case of a voltage unbalance in the phase-sensing system The output of the phase detector for a .4 db unbalanc has been plotted in Figure 20 where it can be seen tha

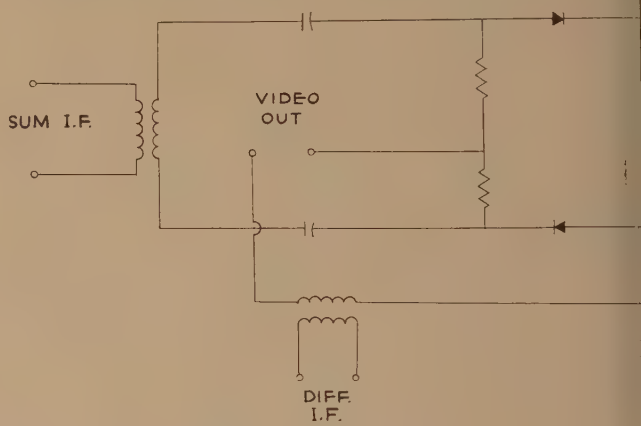


Figure 18. Phase sensitive amplitude detector.

the output is the same as for no voltage unbalance. Th presence of the gradual phase reversal (Figure 17 compensates for the "filling in" of the null (Figure 15) This clearly shows the advantage of using a phase sensitive amplitude detector in an application wher precomparator voltage unbalances are anticipated. A similar advantage is derived in the amplitude-sensin system having a pre-comparator phase shift.

Local Oscillator

The following calculations are performed to investi gate how the phase angle of the I.F. voltage change a a function of the phase angles entering the mixers fro the local oscillator.

The mixer crystal current can be expressed by a Taylo Series of the general form

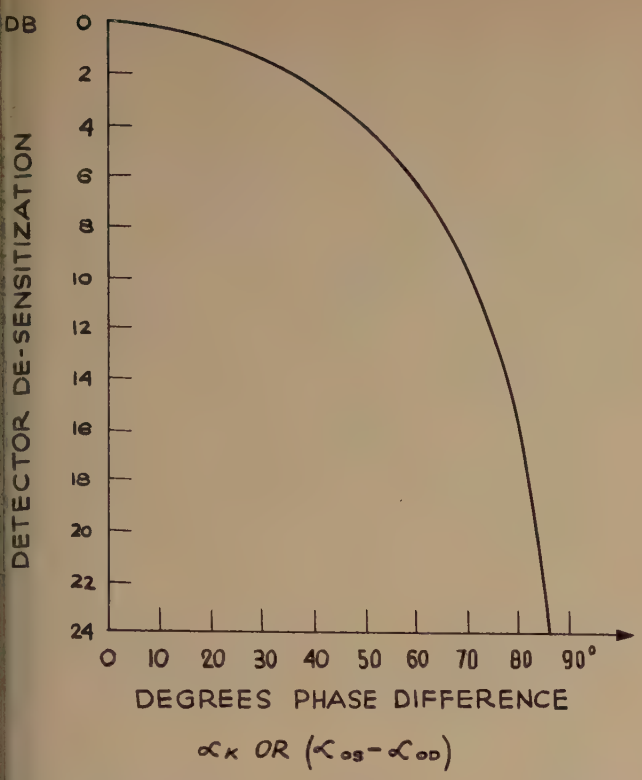
$$i_c = a_1 e + a_2 e^2 + a_3 e^3 + - - - - - a_n e^n$$

The local oscillator voltage at the difference mixer is

$$K_{OD}\sin(\omega_o t + \alpha_{OD})$$

ω_o = local oscillator angular velocity

α_{OD} = local oscillator phase angle



igure 19. Phase detector desensitization vs. post comparator phase shift.

K_{OD} = arbitrary amplitude factor

The entire signal presented to the difference channel ixer is

$$e_D = K_D \sin(\omega_c t + \alpha_D) + K_{OD} \sin(\omega_o t + \alpha_{OD})$$

After substituting this value in the Taylor Series and lecting the term which represents the signal which ould pass through the I.F. amplifier, we obtain for ie difference channel:

$$e_{D\,(IF)} = a_D K_D K_{OD} \cos[(\omega_c - \omega_o)\, t + (\alpha_D - \alpha_{OD})]$$

nd similarly one can obtain for the sum channel

$$e_{S\,(IF)} = a_S K_S K_{OS} \cos[(\omega_c - \omega_o)\, t + (\alpha_S - \alpha_{OS})]$$

Where α_{OS} is the phase angle of the local oscillator ignal presented to the sum channel and K_{OS} the impli- ide factor associated with the local oscillator.

If the phase of the two signals are compared, $(\alpha_S - \alpha_D)$ - $(\alpha_{OS} - \alpha_{OD})$, it can be seen that the term $(\alpha_{OS} -$ $_{OD})$ introduces a constant phase shift, but does not hange the point of phase reversal by itself. However, his phase shift $(\alpha_K = \alpha_{OS} - \alpha_{OD})$ should be compen- ated for in the I.F amplifier because it would tend to esensitize the detector as shown previously in Figure 19. foreover if the radar set were tunable and $(\alpha_{OS} - \alpha_{OD})$ hanged as a function of frequency, it would be difficult o compensate for in the I.F. amplifiers. In such a case, the arious lengths of local oscillator plumbing should be near- y equal so that α_{OS} and α_{OD} would remain constant over he frequency range.

It is also important in such a radar system to maintain he amplitudes of the local oscillator signals (K_{OD} and $_{OS}$) at a constant value to optimize noise figure and naximum conversion gain.

Conclusions

Some analogies may be drawn between the amplitude-sensing and phase-sensing monopulse systems. In the amplitude-sensing system any voltage unbalance (before and in the comparator) will cause a boresight shift; while in the phase system any phase shift before and in the comparator causes a boresight shift. On the other hand any pre-comparator phase shift in the amplitude system will cause a reduction in the null depth while any voltage unbalance before and in the comparator in the phase system will cause null depth reduction. Also, a pre-comparator phase shift in the amplitude system and a pre-comparator voltage unbalance in the phase system would each cause a more gradual phase reversal at boresight. Under these conditions post-comparator phase shifts will produce second order boresight shifts.

In the amplitude system the shape of the antenna patterns, the beamwidth ϵ and beam separation ψ, affect the magnitude of null depth and boresight shift. Within limits it is desirable to have a large $\frac{\psi}{\epsilon}$ ratio and a small ϵ.

In the phase-sensing system the separation between antennas, d, and the operating wavelength, λ, affect the magnitude of the null depth and the boresight shift. Within limits it is desirable to have a large $\frac{d}{\lambda}$ ratio and a beamwidth such that

$$\phi\left(\frac{2\pi d}{\lambda} \sin\theta\right) < \pm 180°.$$

The sum and difference patterns from both systems are similar and the processing of the information can be the same for both systems. After the comparator any phase shifts or voltage unbalances which occur do not directly affect the position or the null depth, but will influence the sensitivity of the detector.

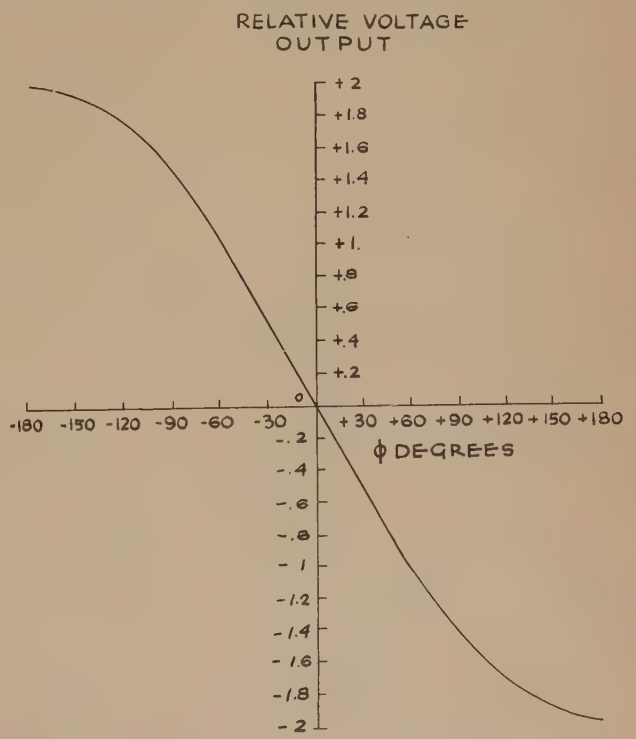


Figure 20. Output of phase detector with pre-comparator voltage unbalance (phase-sensing system.)

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List of Symbols

a, a_2, a_3 Coefficients in Taylor Series
d Distance between Feedhorn Centers
e_D Difference I.F. Signal Voltage
e_S Sum I.F. Signal Voltage
E_D Signal Voltage in Difference Channel
E_{D2} Signal Voltage in Difference Channel with Voltage Unbalance
E_S Signal Voltage in Sum Channel
E_{S1} Signal Voltage in Sum Channel with Phase Shift
E_{S2} Signal Voltage in Sum Channel with Voltage Unbalance
E_o Output Voltage from Phase Detector
f Focal Length of Paraboloid Antenna
h Loss in Channel B
i_c Mixer Crystal Current
K Ratio of Signal Voltage Loss in Channel B to Channel A
K_1 Received Signal Level in a Single Feedhorn
K_D Amplitude of Difference Signal
K_{D1} Amplitude of Difference Signal with Phase Shift
K_{D2} Amplitude of Difference Signal with Voltage Unbalance
K_S Amplitude of Sum Signal
K_{S1} Amplitude of Sum Signal with Phase Shift
K_{S2} Amplitude of Sum Signal with Voltage Unbalance
K_{OD} Amplitude of Local Oscillator Signal at Difference Mixer
K_{OS} Amplitude of Local Oscillator Signal at Sum Mixer
l Ratio of Signal Voltage in Channel B to that in Channel A
K_p Parabolic Antenna Constant (.6)
M_A Slope of Lobe A Near the Boresight Axis
M_B Slope of Lobe B Near the Boresight Axis
n Distance between Phase Center of Closely Spaced Feedhorns
S Extra Path Delay in Antenna B
α_D Phase Angle of Difference Signal Voltage
α_{D1} Phase Angle of Difference Signal Voltage with Phase Delay γ
α_{D2} Phase Angle of Difference Signal Voltage with Voltage Unbalance
α_K Phase Shift Between Sum and Difference Channels (After the Comparator)
α_S Phase Angle of Sum Signal Voltage
α_{S1} Phase Angle of Sum Signal Voltage with Phase Delay γ
α_{S2} Phase Angle of Sum Signal Voltage with Voltage Unbalance l
α_{OD} Phase Angle of Local Oscillator Voltage at Difference Mixer
α_{OS} Phase Angle of Local Oscillator Voltage at Sum Mixer
γ Spurious Phase Shift
ϵ Beamwidth of Each Lobe
θ Angle of Return Signal Wavefront with Respect to the Plane of the Antenna Apertures (See Figures 1 & 2)
θ_{NA} Angle at which the First Null of Lobe A Occurs $0° > \theta > -90°$
θ_{NB} Angle at which the First Null of Lobe B Occurs $0° > \theta > -90°$
θ_S Boresight Shift
λ Wavelength of Carrier
π 3.14
ϕ Phase Delay Due to Distance S
ψ Separation Between Lobes
ω_c 2π Carrier Frequency
ω_o 2π Local Oscillator Frequency

Editor's Note: For the readers' convenience, two previously published figures, to which the authors have referred in this part, are reprinted.

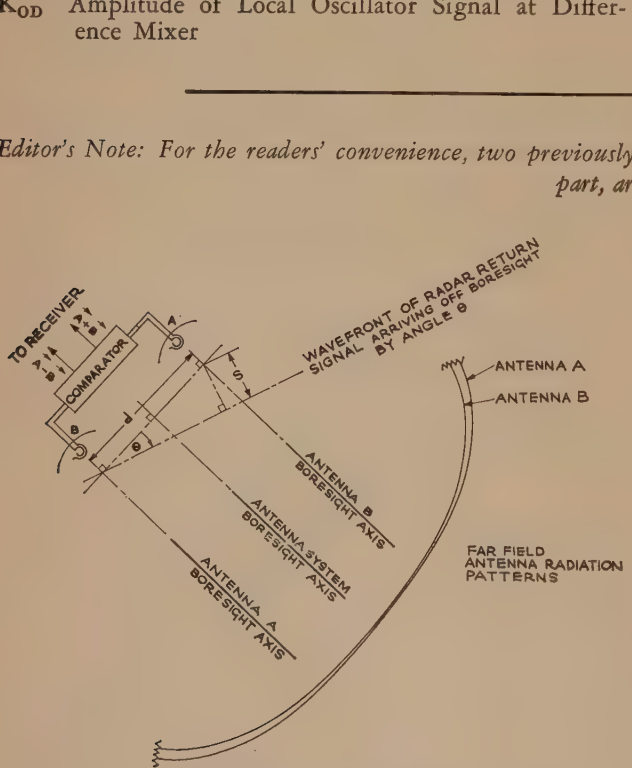

Figure 1 — Phase-sensing antenna configuration.

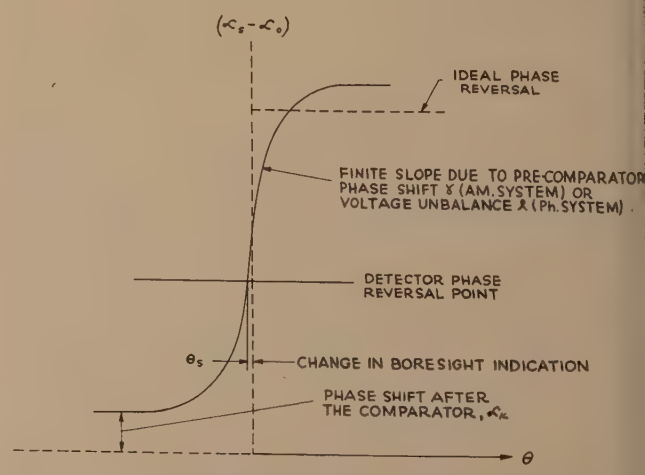
(α_s - α_o)
IDEAL PHASE REVERSAL
FINITE SLOPE DUE TO PRE-COMPARATOR PHASE SHIFT γ (AM. SYSTEM) OR VOLTAGE UNBALANCE λ (Ph. SYSTEM)
DETECTOR PHASE REVERSAL POINT
θ_S
CHANGE IN BORESIGHT INDICATION
PHASE SHIFT AFTER THE COMPARATOR, α_K
θ

Figure 8 — Boresight shift due to pre-comparator and post comparator phase shifts. (Amplitude-sensing monopulse.

A SIMPLIFIED APPROACH TO THE DESIGN OF BANDPASS FILTERS IN WAVEGUIDE

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ıtroduction

This paper presents, in as simple a anner as possible, the practical ethods and equations for bandpass aveguide filter design. It is not the tent of this paper to cover design ieory since this subject has been ıvered extensively by many authors. nly the absolute minimum of back- ound theory necessary to under- and and apply the equations and ethods is given so that there is tle chance for confusion or misin- rpretation.

The equations used have been care- ılly selected from the literature on e basis of simplicity and accuracy results obtained. The unique as- ct of the paper is the "cook book" shion in which it is presented and e inclusion of many practical as- cts of waveguide filter design hich are invaluable to the designer, it somehow have always managed escape publication.

ısic Considerations

It is assumed that the reader is miliar with resonant cavity struc- res in waveguide. If not, one of e best treatments of the subject given in Reference 1. All of the formation given in this paper per- ins to resonant cavities employing ductive irises as coupling elements, ace their use is preferred over ca- ıcitive elements due to their better ıwer handling capabilities, relative se of fabrication, and the fact that ey are less critical mechanically. ecause the unloaded Q, or inherent of the individual cavities is so ıportant from its effect on insertion ss, it should be pointed out here at the unloaded Q (Q_o) is some- hat dependent upon the physical nfiguration of the coupling in- ıctances. There are four practical rms which the inductance may take ıd they are shown in Figure 1.

The forms shown in Figure 1 are arranged according to the value of cavity Q_o obtainable; that is, round-hole coupling shown in Figure 1.a. offers the highest Q_o, while centered-post coupling shown in Figure 1.d. offers the lowest Q_o. The configurations in between offer intermediate values. The choice of which type to use in a given application depends on a compromise between ease of fabrication and performance.

Since the spacing between the two inductances forming the cavity in a narrow band filter is more critical than that which can be held by ordinary fabrication techniques, a capacitive screw and locknut usually is provided in the middle of the top wall for tuning the cavity to the proper resonant frequency. The introduction of the screw into the waveguide effectively lengthens the cavity, or lowers the resonant frequency. Therefore, if tuning screws are to be used, the cavity must be made slightly shorter than that actually required for resonance at the design frequency. In order to keep the insertion loss from rising, the screw penetration should be kept to an absolute minimum. A more important consideration is the screw material itself, since the use of stainless steel or other lossy metals can increase the insertion loss markedly. Therefore, all tuning screws should be silver plated if possible. Obviously, the inside surfaces of the cavity should also be silver plated or of solid copper construction for the best results. Unplated aluminum is often used in lightweight waveguide filters, but theoretically, the dissipative loss due to aluminum is approximately 30 percent higher than that of silver or copper.

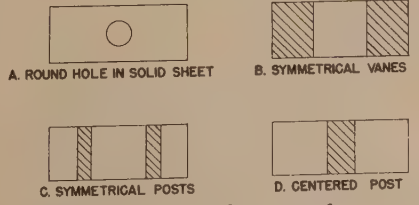


Figure 1. Practical inductances for waveguides.

In most cases of filter design, the inductive susceptances of the coupling irises at the frequency of interest must be known. This is especially true of direct coupled filters where the susceptances of two connected cavities are combined into one overall susceptance. To determine accurately susceptance versus iris size, a sample is made up in which the iris opening or post size can be varied. For normalized susceptances of magnitude approximately 3 or less, the susceptance is determined by VSWR measurements of the sample loaded by a nonreflecting waveguide termination. The VSWR is converted to susceptance by the following formula:

$$B\,(\text{susceptance}) = -\frac{VSWR - 1}{\sqrt{VSWR}}$$

For values of normalized susceptance of magnitude greater than 3, better accuracy is obtained by measuring the insertion loss of the sample and converting the insertion loss directly to susceptance by the following formula:

$$B = -2\sqrt{10^{A/10} - 1}$$

where: A = insertion loss in db
From this information, an accurate curve can be plotted which relates the normalized susceptance to the iris opening or post position.

It should be noted here, however, that when making measurements of susceptance by the insertion loss method that it is essential that both the generator and load be well matched to Z_o. For optimum results, these VSWR's should preferably not exceed 1.02.

In general, the waveguide filter designer is faced with a considerable number of choices as to configuration and response shape when given a particular filter to design. The most basic choice is between direct coupled cavities and quarter wave coupled cavities. In most cases, the choice between the two is quite arbitrary,

and the preference is somewhat controversial, with proponents on both sides. For wide band filters (e.g., one-half percent bandwidth on up), it is generally agreed that the direct-coupled filter is the better choice, since the susceptances required are easily realized and the unit is considerably shorter than an equivalent quarter-wave design. However, for bandwidths of less than one-half percent, the individual susceptances required become quite large for direct-coupled cavities (e.g., $|B| > 100$), and it is this fact which causes the differences of opinion. The proponents of quarter-wave filters feel that the much smaller susceptance values require less critical tolerances and that more accurate measurements of susceptance can be made. Also, the quarter-wave filter is composed of individual cavities which can be evaluated and adjusted quickly and easily for the exact values of loaded Q and resonant frequency required.

On the other hand, the proponents of direct-coupled filters state that with the proper choice of iris configuration, such as the round hole shown in Figure 1.a., the mechanical tolerances are no more critical for the high susceptance values than those of the lower susceptance values employing symmetrical vanes or post irises. As for the accuracy of susceptance measurement, the advocates of direct-coupled design feel that the additional accuracy gained when measuring small susceptances is lost when the two equivalent susceptances of the quarter-wave design are put in series. Therefore, since each point of view has some merit, the choice is left to the individual designer and his application.

The next choice is the pass band response shape. To achieve maximum rejection with a minimum number of sections dictates the use of Tchebycheff ripple in the pass band. Whether the ripple factor is large or small, the Tchebycheff design will always yield a filter with fewer elements than a unit made up of identical sections or a maximally flat design with the same bandwidth and rejection at the edges of the stop band. In general, as the ripple factor is made larger, the rejection for a given bandwidth will increase, but the ripple factor should be kept as small as the corresponding maximum VSWR that can be tolerated in the pass band. In other words, if a 1.10 VSWR is the maximum allowable in the pass band, then the maximum ripple factor cannot exceed 0.01 db. If the maximum VSWR in the pass band is critical, then it is suggested that the filter be designed for somewhat lower VSWR than desired to allow for a certain amount of mechanical inaccuracy. If, for one reason or another, no ripples can be tolerated in the pass band, then the maximally flat design should be used. However, it should be noted that, in the maximally flat case, a perfect match is possible at one frequency only, although the mismatch is generally acceptable over a reasonably wide portion of the frequency band between the 3 db points.

The number of cavities, or sections required to achieve the desired characteristics is the next consideration. This choice usually is made after the response characteristic has been decided upon and can be determined from the appropriate equations given later in this paper. The minimum number of sections required should always be used because extra sections will increase the insertion loss in the pass band due to increased dissipation loss. Since most filter design requirements state a maximum allowable limit on total insertion loss in the pass band due to dissipation and reflection, an accurate prediction of the results to be expected of a particular design is very useful. Until recently, the methods for computing insertion loss were quite cumbersome and inaccurate. However, accurate calculations of the total insertion loss can now be made simply and quickly by using the equations developed by S. B. Cohn (Reference 7). The total insertion loss at resonance, including the effects of dissipation, is given very closely by the following equation:

$$L_o = 4.343 \frac{\omega'_1}{w} \sum_{i=1}^{n} \frac{g_i}{Q_{oi}}$$

where:

L_o = insertion loss in db

ω'_1 = angular frequency as defined in Figures 3 and 4

w = bandwidth of filter $(f_2 - f_1)/f_0$

Q_o = unloaded Q of cavities

g_i = protype filter elements as defined in Figures 2, 3, and 4

n = number of resonators

This formula applies accurately when the mismatch loss at f_o is small, and when the loss does not exceed 1 or 2 db per cavity. When a substantial mismatch loss is present at f_o, as in the case of a Tchebycheff filter with n even, the insertion loss will usually lie between the value given in the equation and that value plus the mismatch loss.

Cohn also gives an exact equation and method for computing the total insertion loss of the dissipative filter at any point in the complete response characteristic, but this is beyond the scope of this paper. It should be mentioned, however, that the presence of dissipation alters the theoretical response of the nondissipative filter by increasing the minimum insertion loss, rounding the pass band shape, and by partially or completely obliterating the ripples. Therefore this fact should be kept in mind when using the design formulas given later in this paper, since all these formulas assume nondissipative cavities. For a more complete discussion on this subject and its implications, the reader is referred to Reference 7.

Direct Coupled Filters

By far the most useful reference for direct coupled filter design is the one by S. B. Cohn (Reference 2). This paper treats both the maximally flat and Tchebycheff cases. Before getting into the specific equations developed by Cohn, a short discussion on the basic theory is necessary.

All of Cohn's design formulas for direct coupled filters are based on the low pass filter prototype shown in Figure 2. The following assumptions are made; (1) The pass band edge occurs at $\omega' = 1$; (2) The left hand load resistance is 1 ohm; (3) The first element, g_1 is a shunt capacitance. The shunt capacitance values are given in farads, and the series inductances are in henries. The right hand resistance r, is one ohm for all cases considered, except for the case of the Tchebycheff response with n even. Also, with the exception of the Tchebycheff response with n even, the g values are symmetrical

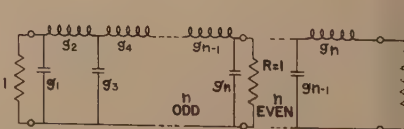


Figure 2. Low pass filter prototype.

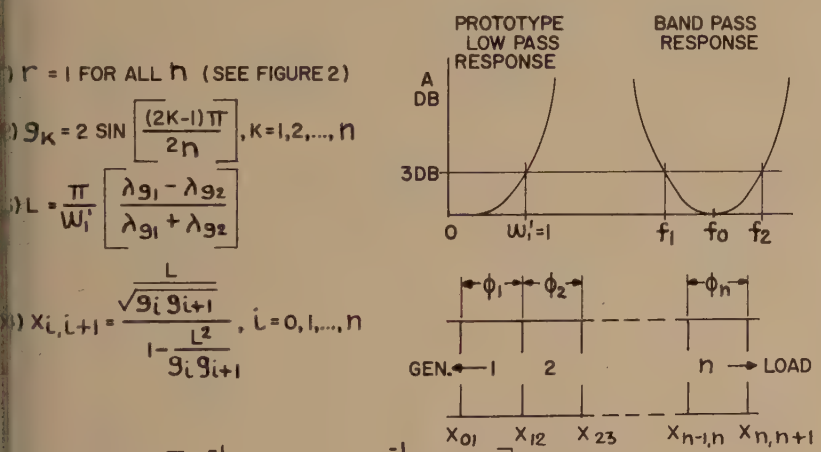
he design equations for both the aximally flat and Tchebycheff re-onses are given in Figures 3 and respectively.

It has been found from experience at the formulas given yield excel-nt results when accurately meas-red values of susceptances are used. lthough Cohn's formulas are all in rms of normalized reactance (X) stead of normalized susceptance B), no problem should be encoun-red in transforming from one to e other since $B = -1/X$.

If for some reason, the bandwidth the completed filter model is too ide or too narrow, it can be ad-sted by changing all of the sus-ptances in the filter by a suitable nount. This amount is determined the percentage change in band-idth required. In general, the in-rnal susceptances should be changed in magnitude by the percentage change required, and the end susceptances should be changed by an amount equal to one half this percentage. If the filter bandwidth is too wide, the susceptances should all be increased in magnitude, and conversely, if it is too narrow, the susceptances should all be reduced in magnitude. For example, if the bandwidth is too wide by 10 percent, the magnitudes of the inner susceptances should all be increased by 10 percent and the end susceptances by 5 percent.

In the case of Tchebycheff filters, if the ripples do not agree with the theoretical values, the difficulty can probably be traced to mechanical inaccuracies in the construction of the unit or tuning inaccuracy, rather than trouble with the basic design. However, it should be kept in mind that the presence of normal dissipation in the cavities will tend to reduce the ripple amplitudes somewhat, especially in the case of small ripples. In fact, ripples of less than 0.1 or 0.2 db will probably be completely obliterated by dissipation.

A word of explanation is given here to clarify the differences between Tchebycheff filters with n odd and n even. As the equations show, in the case of n even, the terminating resistance is not equal to unity and the g values are not symmetrical. However, the only major difference between the response characteristics is that with n odd the VSWR is equal to unity at the frequency corresponding to λ_{g_0}, while with n even the VSWR at this frequency is equal to the maximum ripple value. In either case, the filter itself is a symmetrical structure.



) $r = 1$ FOR ALL n (SEE FIGURE 2)

) $g_K = 2 \sin\left[\frac{(2K-1)\pi}{2n}\right]$, $K = 1,2,\ldots,n$

) $L = \frac{\pi}{W_1'}\left[\frac{\lambda g_1 - \lambda g_2}{\lambda g_1 + \lambda g_2}\right]$

) $X_{i,i+1} = \frac{L}{\sqrt{g_i g_{i+1}}} \Big/ \left(1 - \frac{L^2}{g_i g_{i+1}}\right)$, $i = 0,1,\ldots,n$

) $\phi_i = 180° - \frac{1}{2}\left[\tan^{-1}(2X_{i-1,i}) + \tan^{-1}(2X_{i,i+1})\right]$, $i = 1,2,\ldots,n$

) $A = 10 \log_{10}(1 + W'^{2n})$ DB, (SEE NOTE BELOW)

WHERE

$g_1, g_2, \ldots, g_n$ = PROTOTYPE ELEMENTS IN FARADS AND HENRIES (SEE FIG. 2)

$g_0 = L$; $g_{n+1} = L/r$ ($r = 1$ FOR MAXIMALLY FLAT)

$\lambda g_1, \lambda g_2 = \lambda g$ EVALUATED AT f_1 AND f_2

$\lambda g_0 = \frac{1}{2}(\lambda g_1 + \lambda g_2)$; f_0 IS FREQUENCY CORRESPONDING TO λg_0

W_1' = PASS BAND EDGE OF PROTOTYPE FILTER (SEE NOTE BELOW)

$X_{i,i+1}$ = NORMALIZED IRIS REACTANCE AT λg_0

ϕ_i = PHASE LENGTH AT λg_0

NOTE:

THE INSERTION LOSS RESPONSE (EQUATION 6) MAY BE CALCULATED AT ANY FREQUENCY (USING λg) BY USING THE FOLLOWING EXPRESSION FOR W'

$$\frac{W'}{W_1'} = 2\left(\frac{\lambda g_0 - \lambda g}{\lambda g_1 - \lambda g_2}\right)$$

W_1' SHOULD BE GIVEN THE VALUE 1 IF THE PASS BAND EDGE INSERTION LOSS IS 3 DB. OTHERWISE, W_1' SHOULD BE GIVEN THE VALUE THAT CORRESPONDS TO THE DESIRED EDGE INSERTION LOSS IN THE LOW PASS PROTOTYPE FUNCTION.

Figure 3. Formulas for direct coupled maximally flat waveguide filters.

Quarter-Wave Coupled Filters

Although Cohn (Reference 2) does not specifically state the fact, his equations for direct coupled filters can be extended to the case of quarter-wave coupled filters by a few additional simple steps which renormalize the low pass prototype filter from $\omega' = 1$ to $\omega_c = \omega_a - \omega_b$ (where ω_a and ω_b correspond to f_1 and f_2 in Figures 3 and 4), and then convert to a band pass structure by resonating all shunt capacitances with appropriate values of inductance and all series inductances with appropriate values of capacitance. Then the loaded Q's of each resonant structure can be calculated from the conventional low frequency equations for Q. The steps given above are shown clearly in Figure 5 by drawing the equivalent circuits (neglecting terminating resistances, which are equal to unity throughout) and giving the basic equations which apply.

Actually, Figure 5 and the discussion which pertains to it are included only for background theory, since all of this work can be circumvented by using a simple equation for the Q of the individual cavities which has been derived on the basis of the theory just given. This equation is given below:

$$Q_K = \frac{\omega_0}{\omega_c}\left(\frac{g_K}{2}\right)$$

where,

Q_k = loaded Q of individual cavity

$\omega_o = \omega$ at center frequency

ω_c = bandwidth $(\omega_a - \omega_b)$

g_k = g's defined in Figure 3 .

The loaded Q values and the resonant frequencies for each cavity in a quarter-wave coupled filter actually give sufficient information to design such a filter, since a cavity can be built for each section, and from these two parameters, the iris sizes and cavity lengths can be adjusted until the Q_L and f_o agree with the calculated values. Of course, the connecting line lengths must also be calculated for the filter, and the procedure for this is given later in the paper.

The step by step procedure for the design of both maximally flat and Tchebycheff quarter-wave coupled waveguide filters is given in the following sections.

1. *Maximally Flat Response*

The classic reference for this type of filter is the paper by Mumford (Reference 3). Actually, either Mumford's method or the one given above using Cohn's equations give essentially the same results. However, the method given above using Cohn's equations is more useful for Tchebycheff filters because Mumford's paper treats only the maximally flat case. For the sake of completeness, Mumford's equations will be used here.

Mumford's paper is quite detailed and he expresses his equations in several different forms. For simplicity only one form of each is given here.

a. The total loaded Q of the filter is calculated first from the following equation:

$$Q_r = \left| \frac{1}{\frac{f_c}{f_o} - \frac{f_o}{f_c}} \right|$$

where f_o = resonant frequency

f_c = frequency at 3 db point

b. The number of sections needed for the required response can be determined by substituting different values of n in the next equation for the response:

$$\frac{P_o}{P_L} = 1 + \left[Q_T \left(\frac{f}{f_o} - \frac{f_o}{f} \right) \right]^{2n}$$

where

$\frac{P_o}{P_L}$ = ratio of power available to power delivered to load

f = frequency of interest

c. The individual cavity loaded Q's are then calculated from the following equation:

$$Q_r = Q_T \sin \left(\frac{2r - 1}{2n} \right) \pi$$

d. As mentioned above, the individual Q's and f_o are actually sufficient to define each cavity; however, considerable cut and try effort is saved by calculating the normalized susceptance (B) and the length of the cavities by the expressions given by Mumford. The loaded Q of a rectangular cavity is given in terms of B by the following equation:

$$Q_L = \frac{\tan^{-1} \frac{2}{B}}{2 \sin^{-1} \frac{2}{\sqrt{B^4 + 4B^2}}} \doteq \frac{\sqrt{B^4 + 4B^2}}{4} \tan^{-1} \frac{2}{B}$$

To find the corresponding value of B for a given Q requires a trial and error solution of this equation; however, this is not necessary since Mumford plots this equation on Figure 11 in his paper. Although he also gives an equation relating the iris opening versus B, it is suggested that this be determined experimentally by the method outlined earlier in this paper.

Once the appropriate value of B is known for each cavity, the length of the cavity is calculated by the equations given for ϕ in Figures 3 and 4. If capacitive tuning screws are to be used, the lengths arrived at in the calculations should be foreshortened by an amount sufficient to tune the cavity over the required band.

Each cavity should then be built to the calculated dimensions, and experimental adjustments made so that the resonant frequency and loaded Q agree with the required values.

e. The connecting quarter-wave length lines are found by taking the calculated lengths (without tuning screws, even though tuning screws are used) of two adjacent cavities and combining them in the following equation:

$$l_c = \frac{l_1 + l_2}{2} - \frac{\lambda g}{4}$$

This is only for quarter-wave connecting lines. Theoretically, any odd number of quarter-wave lengths can be used, but the practical limit is the three-quarter wavelength line. The three-quarter wave line sometimes is preferred when the length of the filter is not limited since the possibility of interaction between cavities is eliminated. If three-quarter wave lines are used, the above expression for l_c is the same except that $\lambda g/2$ is added to the result.

It has been found that the connecting line lengths are quite uncritical for reasonably high Q cavities. Mumford discusses the added selectivity inherent in the connecting line lengths and derives a $\pi/8$ factor which is to be subtracted from the selectivities (Q_L's) at the adjacent cavities to counteract the added selectivity of the connecting line. However, for narrow bandwidth filters, the factor is negligible and need not be taken into account.

2. *Tchebycheff Response*

The design of a quarter-wave coupled waveguide filter with a Tchebycheff ripple characteristic is accomplished by taking certain applicable portions of each method previously described. The following steps are adhered to:

a. Calculation of the g factors in farads and henries is done in exactly the same manner as for the direct coupled Tchebycheff designs given in Figure 4.

b. Once the g factors are known for the filter, the loaded Q's of each cavity are calculated from the expression given earlier for Q_K. That is

$$Q_K = \frac{\omega_o}{\omega_c} \left(\frac{g_K}{2} \right)$$

c. From this point on, the method s exactly the same as given for naximally flat quarter-wave coupled ilters (steps d and e).

Tuning Multiple Cavity Waveguide Filters

The tuning and alignment of filers with multiple resonant cavities nust be done systematically since rial and error methods are next to vorthless.

Dishal (Reference 4) has deeloped a very useful and fairly simple method of tuning which utilizes he quarter-wavelength phase shift vhich occurs when tuning a cavity rom far off resonance to resonance. n general, the procedure is as follows:

1. All of the tuning screws in the ilter are turned in until each cavity s tuned well below resonance.

2. The filter is then introduced nto the test set-up between a slotted ine and matched detector. The signal generator should be set to the esonant frequency desired in the ilter.

3. The first tuning screw nearest he slotted line is then withdrawn lowly until the standing wave posiion of minimum is shifted exactly λg/4. This tuning screw is then ocked in place.

4. This process of withdrawing ach tuning screw is repeated with ach cavity until the last tuning screw s reached.

5. The last tuning screw is then vithdrawn until minimum insertion oss through the complete filter is noted. All of the tuning screws can hen be trimmed up slightly for optimum response, and then they hould all be firmly locked in place.

Continuously Tunable Multiple Cavity Filters

When a continuously tunable vaveguide band pass filter is desired, he use of rectangular waveguide avities becomes unattractive due to nechanical difficulties. Therefore, if he rectangular waveguide resonant ircuits are replaced by right circular ylinders operating in any of several ircular waveguide modes, gang tunng becomes a relatively simple matter since the resonant length of the avities can be changed by noncontacting plungers. The choice of operating mode is influenced mainly by the extent of the frequency range to be covered. In general, the lower the mode, the greater the frequency range that can be covered without crossing or interfering modes. The modes used most often are the TE_{111} mode, either as a single mode or dual orthogonal modes, and the TE_{011} mode. The insertion loss at resonance will decrease with the use of higher modes; however, even the lowest order circular waveguide mode (TE_{111}) will yield insertion losses less than the best rectangular waveguide cavity. This fact, of course, is due to the extremely high unloaded Q's which can be realized in right circular cylindrical cavities.

The design of tunable filters using cylinders as the resonant circuits is handled in almost exactly the same manner as the rectangular waveguide type. The only real difference is the method of coupling in and out of the cavities. The coupling susceptances can be either slots, circular apertures, or inductive vane irises, but they must be located at certain points along the cavity depending upon which mode is employed and whether or not the end plates or side walls are preferred. Reference 5 gives an excellent treatment of this problem along with a mode chart and the equations which apply.

The resonant cavities used in such a filter can be either quarter-wave coupled or direct coupled; however, if other conditions permit, quarter-wave coupling is preferred since the coupling susceptances are separated, and therefore, are more easily handled. Although some equations can be found for the calculation of susceptances in such a structure, it is much more accurate and simple to build one cavity and measure the susceptance and loaded Q experimentally.

One difficult problem does present itself when more than two cavities are used in a tunable filter. This problem is the resonant frequency tracking of each cavity as the whole unit is tuned. This is because each

(1) $r = 1$ FOR n ODD (SEE FIG. 2)
$r = \tanh^2(\beta/4)$ FOR n EVEN

(2) $\beta = \log_e(\coth \frac{A_m}{17.37})$, A_m IN DB

(3) $\gamma = \sinh(\frac{\beta}{2n})$

(4) $a_K = \sin\left[\frac{(2K-1)\pi}{2n}\right]$, $K = 1, 2, \ldots, n$

(5) $b_K = \gamma^2 + \sin^2(\frac{K\pi}{n})$

(6) $g_1 = \frac{2a_1}{\gamma}$

(7) $g_K = \frac{4a_{K-1}a_K}{b_{K-1}g_{K-1}}$, $K = 2, 3, \ldots, n$

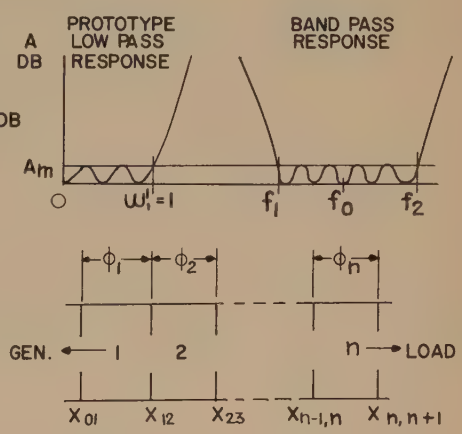
(8) $L = \frac{\pi}{\omega_1'}\left[\frac{\lambda_{g1} - \lambda_{g2}}{\lambda_{g1} + \lambda_{g2}}\right]$

(9) $X_{i,i+1} = \frac{\sqrt{g_i g_{i+1}}}{1 - \frac{L^2}{g_i g_{i+1}}}$, $0, 1, \ldots, n = i$

(10) $\phi_i = 180° - \frac{1}{2}\left[\tan^{-1}(2X_{i-1,i}) + \tan^{-1}(2X_{i,i+1})\right]$, $i = 1, 2, \ldots, n$

(11) $A = 10 \log_{10}\left[1 + (10^{A_m/10} - 1)\cos^2(n \cos^{-1}\omega')\right]$ DB, $\omega' \leq 1$

$A = 10 \log_{10}\left[1 + (10^{A_m/10} - 1)\cosh^2(n \cosh^{-1}\omega')\right]$ DB, $\omega' \geq 1$



NOTE:

ALL DEFINITIONS GIVEN FOR MAXIMALLY FLAT EQUATIONS ON FIG. 3 ALSO APPLY FOR ABOVE EQUATIONS EXCEPT $\omega' = 1$ AT EQUAL RIPPLE LEVEL (A_m) INSTEAD OF 3 DB. THIS ALSO APPLIES FOR INSERTION LOSS RESPONSE CALCULATIONS WHEN USING EQUATIONS GIVEN IN (11) ABOVE.

Figure 4. Formulas for direct coupled Tchebycheff waveguide filters.

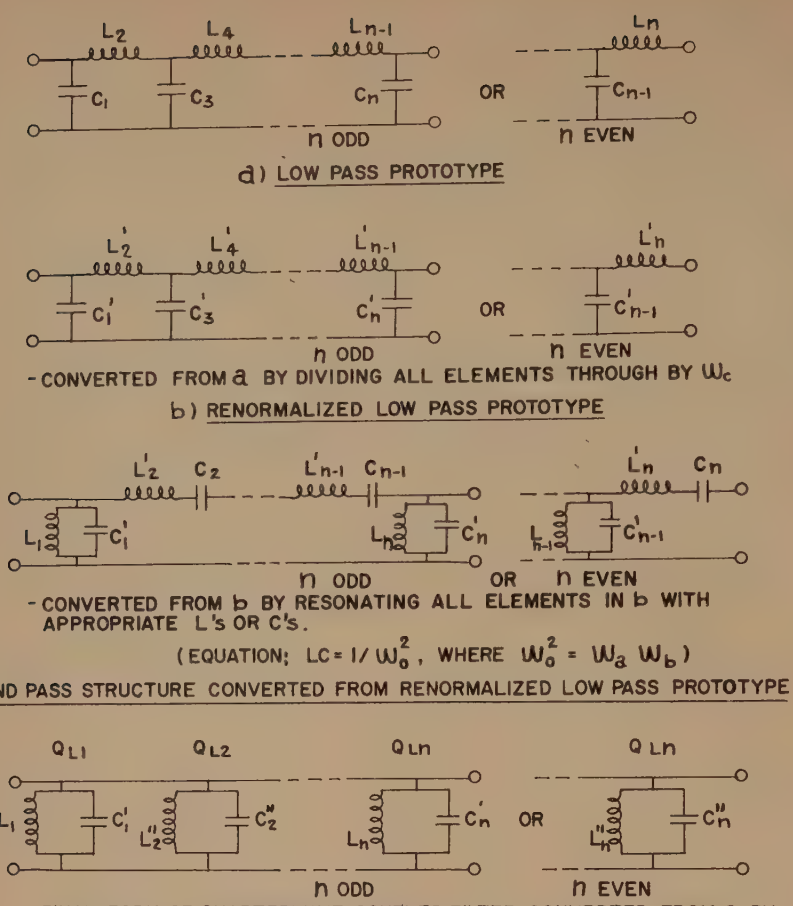

L2 L4 Ln-1 Ln
C1 C3 Cn Cn-1
OR
n ODD
n EVEN
d) LOW PASS PROTOTYPE
L'2 L'4 L'n-1 L'n
C'1 C'3 C'n C'n-1
OR
n ODD
n EVEN
- CONVERTED FROM a BY DIVIDING ALL ELEMENTS THROUGH BY Wc
b) RENORMALIZED LOW PASS PROTOTYPE
L'2 C2 L'n-1 Cn-1 L'n Cn
L1 C'1 Ln C'n Ln-1 C'n-1
n ODD
OR
n EVEN
- CONVERTED FROM b BY RESONATING ALL ELEMENTS IN b WITH APPROPRIATE L's OR C's.
(EQUATION; LC = 1/W0², WHERE W0² = Wa Wb)
C) BAND PASS STRUCTURE CONVERTED FROM RENORMALIZED LOW PASS PROTOTYPE
QL1 QL2 QLn QLn
L1 C'1 L''2 C''2 Ln C'n OR L''n C''n
n ODD
n EVEN
- FINAL FORM OF QUARTERWAVE COUPLED FILTER CONVERTED FROM C BY IMPEDANCE INVERSION OF SERIES RESONANT CIRCUITS.
BASIC EQUATION; QL = W0C SHUNT / 2
d) QUARTER-WAVE COUPLED BAND PASS WAVEGUIDE FILTER

Figure 5. Evolution of quarter-wave coupled band pass filters from low pass prototype.

cavity may have different coupling susceptances and the center cavities will see different impedances than the outside cavities. The solution to this problem is found by plotting the tracking characteristics of each cavity and providing special threads or cams to control the plunger advancement so that all cavities track simultaneously. Another method of attack may be in varying the size of each cavity so that they will track simultaneously under the particular set of conditions; however, this approach is probably the most difficult.

One very attractive method of providing a compact, tunable filter is by the use of orthogonal TE_{111} modes. This approach is discussed by Ragan (Reference 6). The advantage of this type of structure is that one cavity can be made to look like two cavities electrically; that is, the rejection obtainable from one section using dual TE_{111} modes is roughly equivalent to the rejection of two single mode cavities in tandem. Therefore, a high selectivity, low loss, broad band, tunable waveguide filter can be made up by using two dual mode cavities ganged together. The response is roughly equivalent to that of a four cavity filter, and the tracking problems are minimized. Some tracking discrepancies do occur due to slight mechanical differences between the two orthogonal modes and between the cavities themselves, but these differences cannot be avoided entirely. In any case, these discrepancies are not serious since they show up as small changes, or wiggles, in the shape of the passband characteristic as the unit is tuned over the full frequency range. A unit employing these principles is shown in Figure 6. The particular design is continuously tunable over the range of 8.5 to 9.5 Kmc. with a maximum insertion loss of 1.8 db for a 30 Mc. bandwidth. The rejection obtained at $f_o \pm 60$ Mc. is 50 db minimum.

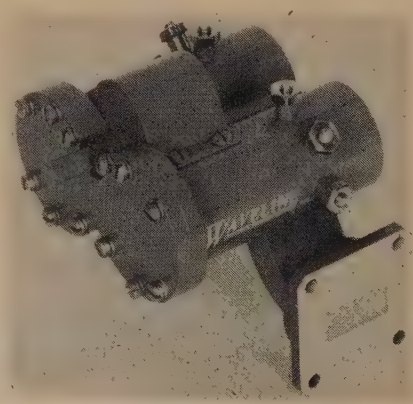


Figure 6. Gang tuned dual TE_{111} mode filter for X-band.

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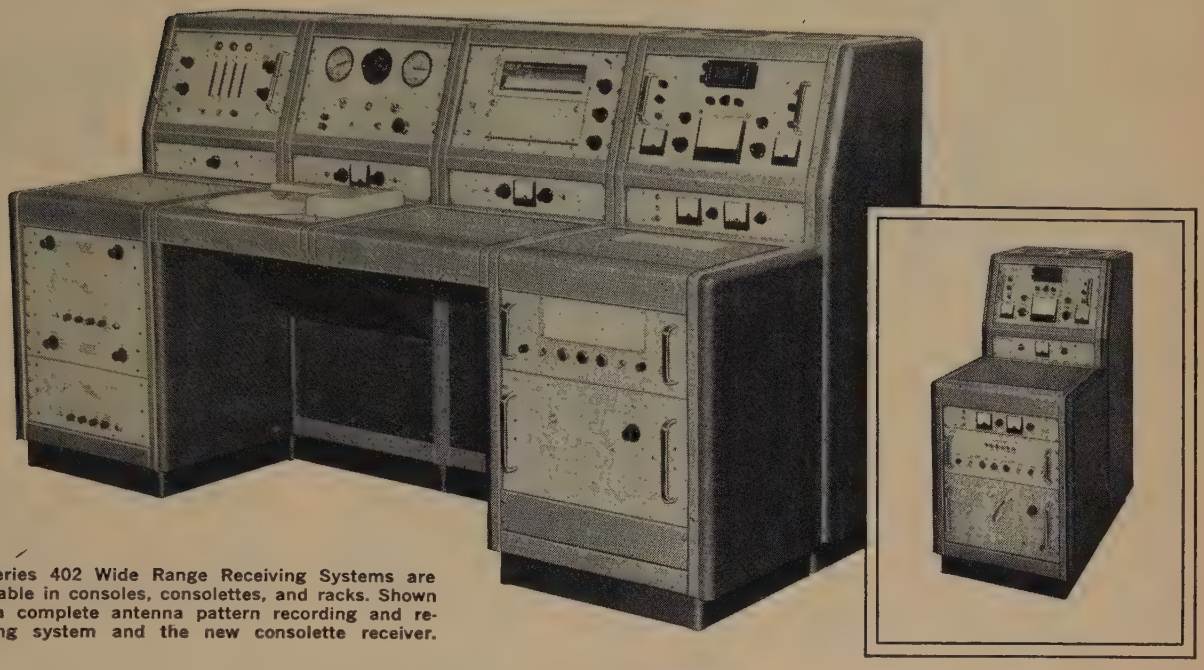
10. J. Reed, "Low Q Microwave Filters," Proc. of the IRE, Vol. 38 (July 1950), p. 793.

MAJORS and MINORS

...A Message to the Antenna Designer



● Series 402 Wide Range Receiving Systems are available in consoles, consolettes, and racks. Shown are a complete antenna pattern recording and receiving system and the new consolette receiver.

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Only from S-A, 1 db Linearity over Full 60 db Dynamic Range

A recent development, S-A's P-4 modification adds 20 db to the normal 40 db dynamic range. The modification takes advantage of the gain vs AGC voltage characteristics of the Series 402. Existing receivers can be modified at the factory.

New Modification Z Broadens Use

Modification Z adds a precision IF attenuator and VTVM to the Series 402. Now RF and microwave signal level, gain, and isolation measurements can be made with fewer components and instruments. *For instance,* an X band 60 db attenuator can be calibrated to within ±0.5 db with a 1 mw signal source, a flap attenuator, a mixer, and an S-A Series 402Z Receiver. Antenna gain can be measured by direct comparison with a standard gain antenna. Signal levels can be compared against a reference standard.

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Modification P-4	500
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3

CIRCLE READER SERVICE CARD 21

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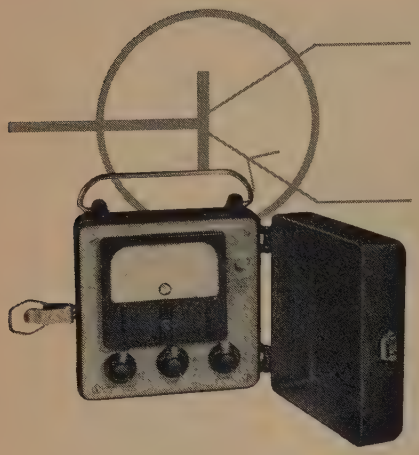

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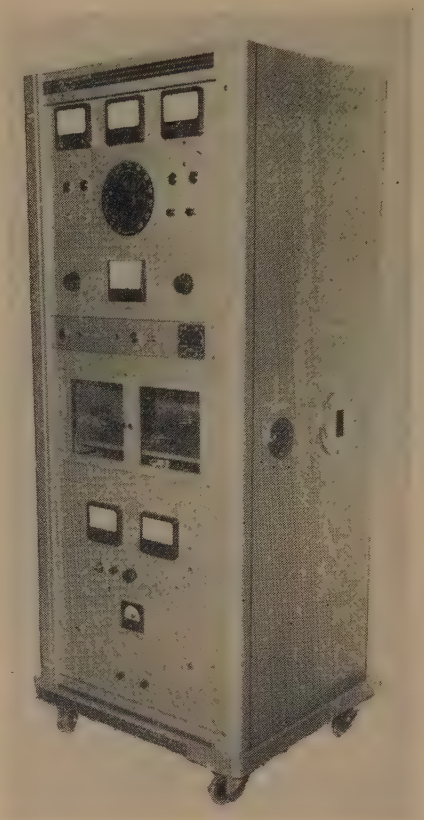
CIRCLE READER SERVICE CARD 22

NEW PRODUCTS

NEW SERIES HIGH POWER R.F. SIGNAL SOURCES NOW AVAILABLE FOR RADAR AND MICROWAVE USE



A new high power R.F. signal source series, the Model 700, is now available to the radar and microwave industry from Burmac Electronics Co., Inc. of Rockville Centre, N.Y. The series is available for C.W., pulse, or dual codes of operation.

Klystrons, pulse magnetrons, C.W. magnetrons, or traveling wave tubes are incorporated as generator elements in the Model 700 lines. Each Burmac unit also features built-in R.F. power monitors, filament regulators, band switching, generator tube protective circuits, vacuum or semiconductor power supplies, personnel/circuit protection and complete control function indicators.

This new Burmac series incorporates optimum wave shape and circuit parameters to insure proper operation of the R.F. generator tube and is available from the ultra high frequency through and including the K-band microwave frequency spectrum. Antenna measurements, component testing and auxiliary transmitter functions are typical applications for the Model 700 series R.F. signal sources. Additional information and application assistance may be obtained by writing the firm.

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NEW!

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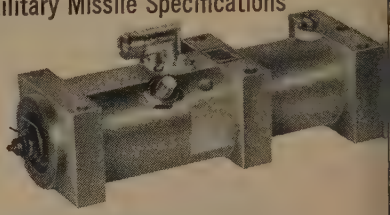

S-BAND PULSE OSCILLATOR

- Minimum 1.5 KW Peak Power Output at .001 duty cycle; 1 μsec pulsewidth 1000 pps
- 300 MC Tuning Range
- Operating Conditions: 3000V at 2.5 amp peak (nominal)

S-BAND CW OSCILLATOR

- Minimum 50 mw Power Output 100 mw at lower frequencies
- Exceeds 400 MC Tuning Range
- Operating Conditions: 125V-250V at approx. 20-35 ma depending on plate voltage.

Both oscillators are lightweight (only 20 oz.) with integrated mountings. Both use 6442 triode tube. Heater 6.3V AC or DC.

S-BAND FILTER-MIXER-DIPLEXER

- Mixer and Diplexer (non-tunable) operate as an integral part of the Filter
- Unit features minimum Insertion Loss, Rejection Bandwidth and Input VSWR.
- Tuning Range: exceeds 300 MC

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Packaged modular control systems built r assembled entirely from stock units, ssemblies and sub-assemblies, are now vailable from Airborne Accessories Corp- ration, Hillside, New Jersey, to manu- acturers in the aircraft, missile, electronic ontrol and related fields.

Systems include transducer, pre-ampli- er, power amplifier, linear or rotary ctuator plus auxiliary equipment as re- uired . . . rectifier, inverter, voltage gulator, etc.

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For many applications, engineers can esign around these systems. In many ther applications, only slight system odification enables these modular units provide the basis for immediately ac- essible systems.

IRCLE READER SERVICE CARD 102

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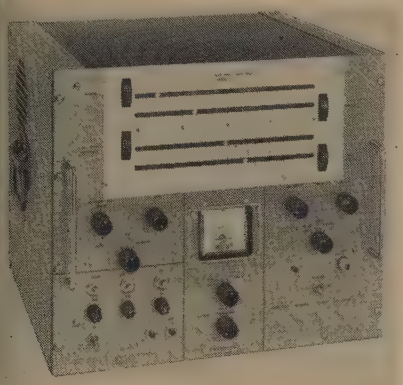
NEW MICROWAVE OSCILLATORS COVER 1-18 KMC



A new series of swept microwave oscilla- rs covering the 1 to 18 kmc frequency nge is now available from Alfred Elec- onics, Palo Alto, California.

Alfred's series 620 models, which offer e broadest frequency range currently vailable, provide electronic sweep of RF utput, or extremely stable CW operation. All models feature linear frequency weep coverage over all or part of each and for rapid evaluation of reflection co- fficient, gain, attenuation and other net- ork transfer characteristics.

Series 620 oscillators offer these two ex- usive features:

1. Two adjustable frequency markers for nvenient calibration of oscilloscopes or corders. Markers save valuable test time indicating either band limits or inter- ediate frequency values.

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W-568-3A-2	12.5-18.0 KMC	20 DB Min.	1.0 DB MAX	1.15 MAX
W-177-1K-1	9.5 KMC ±100 MC	25 DB Min.	.7 DB MAX	1.15 MAX
W-277-3A-3	5.2-5.9 KMC	17 DB Min.	1.0 DB MAX	1.15 MAX
W-859-11A-1	930 ±60 MC	25 DB Min.	2.0 DB MAX	1.25 MAX
W-668-1A-2	8.5 —9.6 KMC	10 DB Min.	0.4 DB MAX	1.10 MAX

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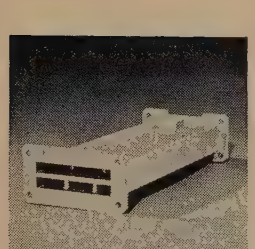
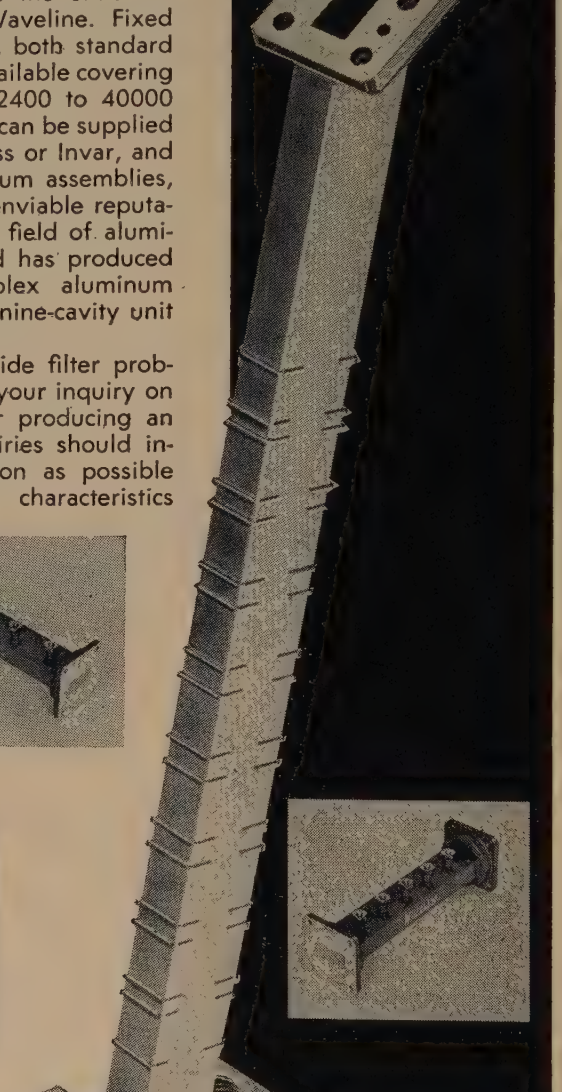
CIRCLE READER SERVICE CARD 24

WAVEGUIDE FILTERS

The filters shown here are a few representative samples of the units designed and produced at Waveline. Fixed tuned or tunable designs, both standard or custom designed are available covering the frequency range of 2400 to 40000 Mc/sec. Filter assemblies can be supplied in either silver-plated brass or Invar, and in aluminum. For aluminum assemblies, Waveline has gained an enviable reputation for leadership in the field of aluminum flux-dip brazing and has produced in quantity many complex aluminum filter designs such as the nine-cavity unit shown at the right.

If you have a waveguide filter problem, we would welcome your inquiry on designing a prototype or producing an established design. Inquiries should include as much information as possible concerning the response characteristics desired.





A four page Waveguide Filter brochure describing some standard designs in detail is available on request.

WAVELINE INC.

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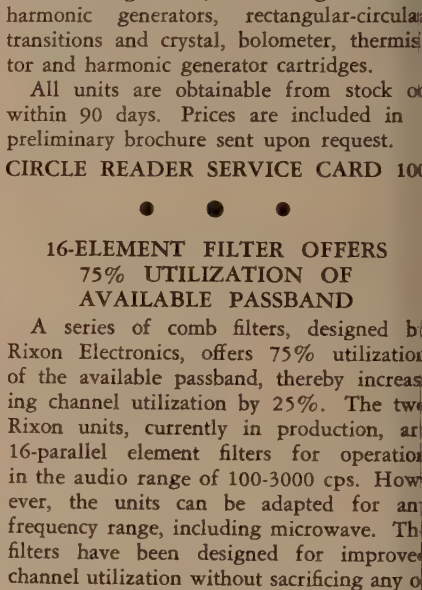
CIRCLE READER SERVICE CARD 25

G-BAND & F-BAND COMPONENTS FROM FXR

FXR, Inc., Woodside, Long Island i now offering a commercial line of recentl developed and proven 2 MM wavelengt (G-Band) and 3 MM wavelength (F Band) components, according to an an nouncement from Henry Feldmann, pres dent of the company. These miniature in struments have frequency ranges from 9 to 140 KMC and 140 to 220 KMC, F-Ban and G-Band respectively. They are th culmination of an extended research an development program the FXR microwav engineering staff undertook for the Cor trolled Thermonuclear Branch of th United States Atomic Energy Commissio and the University of Illinois.



The commercial line is comprised of wave guide and flanges, slotted sections, precisio variable attenuators, detector mounts, E/H tuners, precision phase shifters, frequenc meters, fixed terminations, series shunt an E/H tees, E- and H-plane 90° bends, pre cision sliding shorts, standard gain horns harmonic generators, rectangular-circula transitions and crystal, bolometer, thermis tor and harmonic generator cartridges.

All units are obtainable from stock o within 90 days. Prices are included in preliminary brochure sent upon request.

CIRCLE READER SERVICE CARD 10

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16-ELEMENT FILTER OFFERS 75% UTILIZATION OF AVAILABLE PASSBAND

A series of comb filters, designed b Rixon Electronics, offers 75% utilizatio of the available passband, thereby increas ing channel utilization by 25%. The tw Rixon units, currently in production, ar 16-parallel element filters for operatio in the audio range of 100-3000 cps. How ever, the units can be adapted for an frequency range, including microwave. Th filters have been designed for improve channel utilization without sacrificing any o the other parameters — for example, equa input and output impedances can be ob tained. The units find application wit any type of equipment where these im pedance conditions must be met such as i a cross country transmission telephone sys tem or with various terminal units suc as in feeding from a transmit-receive uni to a computer.

Equal input and output impedances ar obtained by controlling all amplitude an phase characteristics. The attenuatio characteristics for all 16 parallel element are equal but phase characteristics are com plementary so that filter interactions cance out.

Filter units can be used with stationary or mobile equipment and will operate under a wide range of environmental conditions (temperatures: −55° to +125°C; humidity, 0 to 100%; altitudes up to 50,000 ft.). To provide electromagnetic shielding, units are enclosed in an Allegheny "MuMetal" case.

CIRCLE READER SERVICE CARD 105

• • •

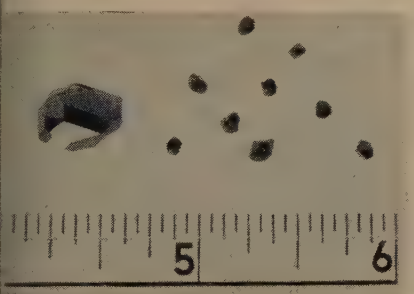
SINGLE CRYSTAL YIG FROM MICROWAVE CHEMICALS LABORATORY

The first single crystal YIG, yttrium iron garnet, to be offered on a commercial basis was announced recently by Bernhard Kramarsky, President of Microwave Chemicals Laboratory, Inc. of New York City.

Mr. Kramarsky indicated that, "These YIG are being manufactured in all sizes up to 0.400" and weigh as much as two grams per crystal. A unique method of producing these YIG has been developed and patents are being filed. At the moment, these crystals are available in limited quantities for research and development purposes."

Mr. Kramarsky pointed out further that, "These crystals have extremely narrow line width, less than five oersteds at microwave frequencies. Their Curie point is 292° C ± 1° C, and the crystals have a lattice constant of 12.373 A ± .003."

In the microwave device field, potential uses for these single crystal YIG are as parametric amplifiers, and as superior substitutes for conventional microwave ferrite single crystals. Single crystal YIG has been successfully used as a Faraday-rotation type IR modulator.



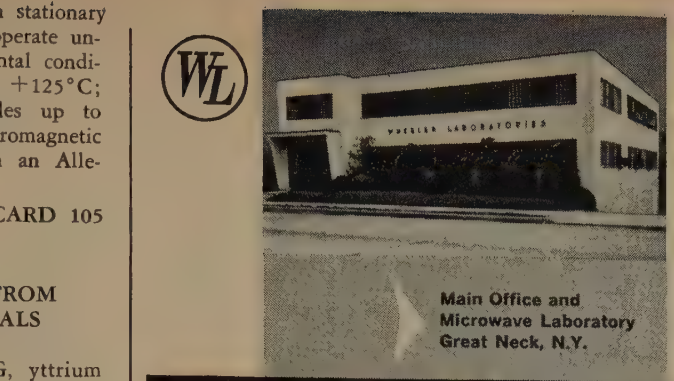
Microwave Chemicals Laboratory expects, according to Mr. Kramarsky, to have even larger single crystal YIG available should there be a need to produce them. The firm also manufactures other rare earth polycrystalline materials to specifications.

CIRCLE READER SERVICE CARD 106

• • •

TUCOR ANNOUNCES AVAILABILITY OF NEW LINE

Tucor, Inc. of South Norwalk, Connecticut, has announced the availability of its first product line — a family of waveguide and coaxial miniature gas tube noise sources covering the most commonly used microwave frequencies of L-band to V-band. The firm began production in mid-August in its 11,700 square foot plant, according to Roger White, president.



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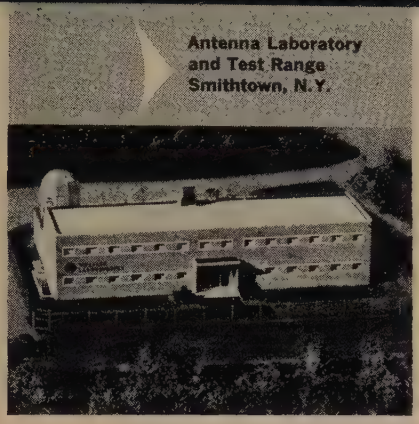

As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

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Practically, if your dish at the moment is along paraboloidal lines, perhaps you could use our help in providing special fabrications in plastics.

Models are our dish, starting with prototype which then leads to full production on a precision basis.

• Fact File describes our facilities

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CIRCLE READER SERVICE CARD 28

A series designated T44-A, are two-terminal waveguide elements—i.e., single-ended circuits designed for installation in branch circuits. These units provide noise outputs up to 21 db above KTB over 10% bandwidths with accuracies of 0.2 db. A series of four terminal waveguide elements (T44-B) is also available. These units, designed for use as series elements in the receiver circuit, feature negligible insertion less in the unfired condition. In the fired condition, they provide noise signals 10 to 18 db above KTB over complete waveguide bandwidths with accuracy suitable for most performance monitoring requirements.

Tucor also will manufacture a series of broadband duplexers, featuring an exclusive electronic de-ionization system for fast cutoff, and a series of miniature TR-type crystal protection device.

CIRCLE READER SERVICE CARD 107

• • •

HIGH TEMPERATURE GLASS-CERAMIC FRIT

A high temperature glass-ceramic frit has been developed by Corning Glass Works for use in stack mount type tube construction.

The thermo-setting solder glass-ceramic has sealing and service temperature of 750 degrees C.

Corning said the frit can be used in sealing aluminosilicate (Corning Code 1723) glasses to themselves, to molybdenum, or to tungsten, and in sealing molybdenum and tungsten to themselves.

The frit will seal other materials which are in the expansion range of 40 to 5[illegible] x 10^{-7} and are capable of withstanding the 750 degrees C sealing temperature. It will seal in vacuum, air, forming gas and nitrogen.

While developed principally for the stack mount type tube construction, the frit also can be used for seals in magnetron, Klystron, and traveling wave tubes where high exhaust bake-out temperatures are required.

CIRCLE READER SERVICE CARD 10[illegible]

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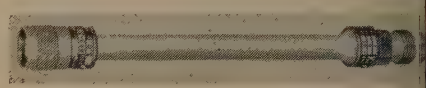
WEINSCHEL 1 TO 12.4 KMC FIXED COAXIAL ATTENUATORS NOW WITH TYPE SC CONNECTORS



Weinschel 1 to 12.4 KMC Fixed Coaxial Attenuators are now available with Type SC Connectors (male/female, double male or double female).

These attenuators are made with Weinschel Film Resistors for maximum stability under pulse power, as well as humidity and temperature cycling. Important specifications are: Frequency Range: [illegible] to 12.4 KMC, Attenuation Range: 1 to 20 db, Impedance: 50 Ohms, Model Numbers: Model 663 — 1 male, 1 female connector; Model 664 — 2 female connectors; Model 665 — 2 male connectors.

CIRCLE READER SERVICE CARD 10[illegible]

Outstanding Design in UHF, VHF, 2-Way and Microwave Antennas

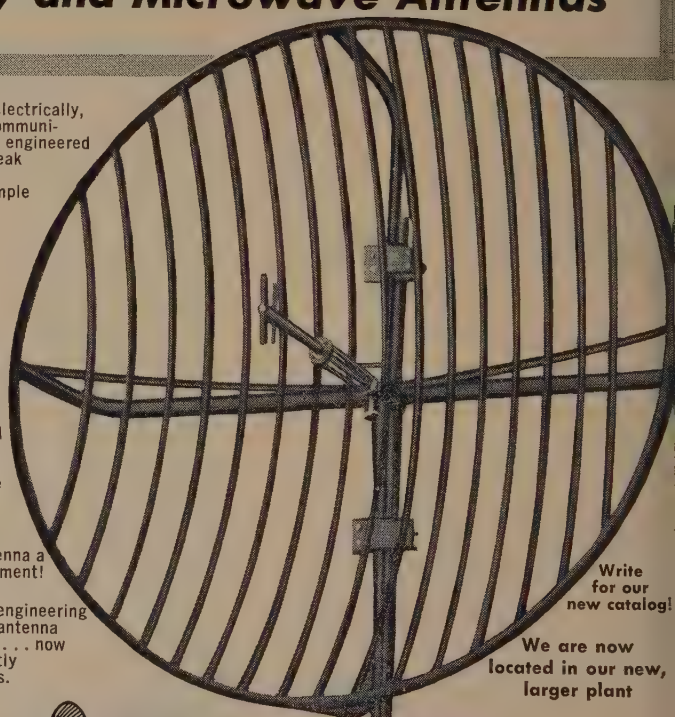
Both mechanically and electrically, Mark Antennas for all communications applications are engineered and manufactured for peak efficiency, maximum mechanical stability, simple installation and long trouble-free life.

PARABOLAS and Point to Point
For 450, 900, 2000 and 6000 MC. Up to 15' diameter. Rugged HELLIARC welded aluminum construction permits lighter, lower cost towers.

2 WAY COMMUNICATIONS
Mark High Gain patented Fiberglas Construction omnidirectional base station antennas provide gains up to 10 db.

RAILWAY and VEHICULAR
New low profile R R antenna a brand new Mark development!

SPECIAL DESIGN
Mark offers a complete engineering and research service in antenna design and manufacture . . . now supplemented with greatly increased plant facilities.



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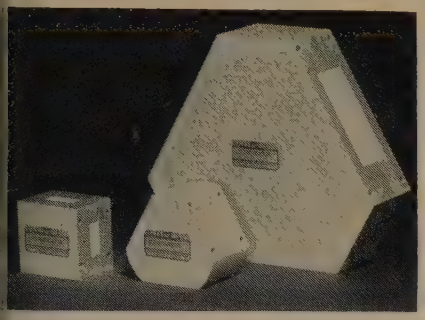
We are now located in our new, larger plant

MARK PRODUCTS
5439 Fargo Avenue ORchard 5-1500, Skokie, Illinois

CIRCLE READER SERVICE CARD 29

NEW CIRCULATORS

Monogram Precision Industries, Inc. — Cascade Research Division has developed and made available a new line of Y, T and Cross-type circulators covering S-G-J-XL-K-K bands. This series is one-tenth to one-fifth the size and weight of corresponding conventional circulators and feature an insertion loss of one-half and an isolation of twice that of other similar circulators. The



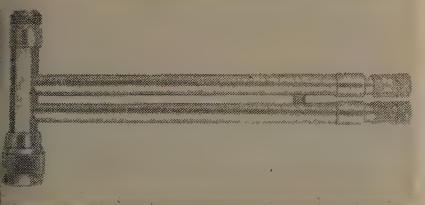
simple mechanical design affords rugged construction, permitting environmental reliability not heretofore possible in conventional models. The new circulators lend themselves ideally to Maser, Parametric Amplifier and duplexer applications.

General Specifications: Peak Power, 100 K.W.; Average Power, 100 watts; Maximum Insertion Loss, 0.5 db; Minimum Isolation, 20 db; Maximum V.S.W.R., 1.2; Frequency Band, 5% or more.

CIRCLE READER SERVICE CARD 110

• • •

EMPIRE'S BROADBAND COAXIAL STUB TUNERS COVER FREQUENCIES FROM 200 to 10,000 MC



Empire Devices' broadband coaxial stub tuners consist of a length of ⅜" concentric line with one, two or three short-circuited variable length stubs at right angles to the main line. These stubs, in turn, are axially separated by ½" or 3" — depending on frequency range — and each stub is a sliding tube with tempered beryllium contact springs. Knurled locking nuts hold the tubes firmly in place once the optimum tuning position has been obtained, to prevent inadvertent mis-adjustment.

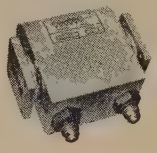
Stub tuners may be used to optimize the power output of microwave oscillators by matching the impedance of the source to the load; to tune out reflections in a coaxial transmission system; to maintain a low VSWR on a transmission line for maximum power transfer within a system; as an impedance transformer; or to provide a DC return for crystal holders or other devices where DC returns are needed.

CIRCLE READER SERVICE CARD 111

More NEW PRODUCT NEWS *on page 61*

Microwave energy normally travels on a two-way street. Because power flow has the habit of being reciprocal, it often becomes vitally necessary for microwave systems engineers to isolate the load from the transmitter or to control power channeling.

Rantec **LOAD ISOLATORS** directionalize the power flow with a minimum loss in one direction of propagation and with extremely high loss in the other. Rantec manufactures a



large number of "off-the-shelf" **LOAD ISOLATORS** which range from low power to liquid-cooled high power units and cover broad band as well as specific frequencies.

Rantec engineers welcome the opportunity of solving specific problems or undertaking special design projects.

rantec *corporation*

calabasas, california

microwave ferrite components / antennas / r-f devices

CIRCLE READER SERVICE CARD 30

AFCRC Plasma Sheath Symposium Program

Plasma sheath problems in their relation to research efforts in airborne antennas, radar cross-section measurements, and allied fields, will be the subject of a three-day symposium sponsored by the Air Force Cambridge Research Center, December 7, 8, and 9 at New England Mutual Hall in Boston.

The first two-and-a-half days will be unclassified with the final session on the third day limited to those who have a Secret security clearance and can establish a "need-to-know."

The program is as follows:

Monday 7 December 1959

8:30 - 9:30 REGISTRATION
Attendees will pick up pocket cards at New England Mutual Hall, 225 Clarendon St., Boston, Mass.

9:30 - 10:00
INTRODUCTORY REMARKS
Welcome to Symposium
by Colonel E. W. Richardson AFCRC
L. M. Hollingsworth AFCRC
Symposium Organization
R. F. Turner AFCRC

10:00 - 12:10
FIRST TECHNICAL SESSION
Chairman: H. Margenau Yale Univ.

10:00 - 10:35 High Frequency Waves in Ionized Gases
S. C. Brown M.I.T.

10:35 - 11:10 Plasma Waves in a Magnetic Field
R. J. Papa M.I.T.

11:10 - 11:40 Peculiar Wave Propagation Characteristics of a Plasma With Constant Magnetic Field
H. Poeverlein AFCRC

11:40 - 12:10 Relaxation Phenomena In Shock Fronts (A Review)
I. P. Shkarofsky, T. W. Johnston, M. P. Bachynski RCA Victor Ltd.

12:10 - 1:30 LUNCH

1:30 - 5:15
SECOND TECHNICAL SESSION
Chairman: N. Marcuvitz P.I.B.

1:30 - 2:00 Experimental and Theoretical Analysis of Radio Signal Interference Effects Due to Ionized Layer Around a Re-Entry Vehicle
W. C. Taylor Lockheed

2:00 - 2:30 Electron Concentration Behind Shocks In Air and in Air With Various Additives Based on Equation of State in Closed Form
A. R. Hochstim Convair

2:30 - 3:00 Effective Scattering Cross-Section and Collision Frequency Associated With High Temperature Air
I. P. Shkarofsky, M. P. Bachynski, T. W. Johnston RCA Victor Ltd.

3:00 - 3:15 INTERMISSION

3:15 - 3:45 Methods for Approximating the Ion Field Surrounding Advanced Missiles
R. L. Daniels North American

3:45 - 4:15 Non-Equilibrium Ionization and Heavier Particle Densities Produced by Shock Waves in Air
J. M. Fiskin, W. B. Sisco, R. A. Batchelder Douglas

4:15 - 4:45 A Comparison of The Ionized Shock Layer About Two and Three Dimensional Blunt Shapes at Hypersonic Speeds
H. W. Ridyard G.E.

4:45 - 5:15 Telecommunications During Re-Entry
K. Baldwin, O. E. Bassett, E. I. Hawthorne Avco
E. Langberg Elcon Labs

5:30 - 7:00 Informal Cocktail Hour at Hotel Lenox

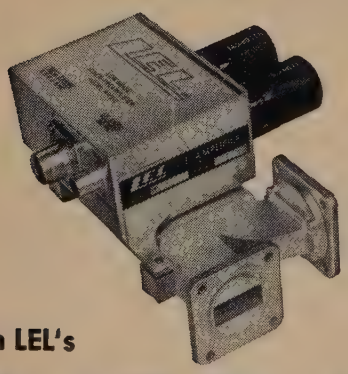
Tuesday 8 December 1959

8:30 - 12:15
THIRD TECHNICAL SESSION
Chairman: W. J. Otting A.F.O.S.R.

8:30 - 9:00 The Region Behind a Body Moving Through a Rarified Ionized Atmosphere
E. T. Kornowski G.E.

9:00 - 9:30 Thermal Ionization Behind Shock Waves In Air
S. C. Lin Avco

MAXIMUM SENSITIVITY



X BAND
MODEL MMX-2

with LEL's

MATCHED MIXER-PREAMPLIFIERS

The MMX-2 is the newest X Band matched mixer-preamplifier assembly offered by LEL. Covering a frequency range of 8.5 to 9.6 KMC, the MMX-2 provides an 8 mc bandwidth, a maximum noise figure of 7.5 db, and a minimum power gain of 25 db. I.F. power output of 0.5 watt across 50 ohms is provided at 30 or 60 mc center frequency. Other microwave receiver front ends are available for C, S, L, and KU bands with integral preselector, local oscillator and AFC circuits if desired.

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CIRCLE READER SERVICE CARD 31

NEW! THE MERCURY "10" SERIES TRIODE CAVITIES

10% tuning range

Fully standardized line for design and production . . . Frequency range from 225mc to top existing tube limits

DELIVERY—30 DAYS OR LESS!

Only JVM offers these outstanding engineering advancements—low cost standardized production—off-the-shelf availability—design flexibility and uniform performance.

Miniaturized MERCURY "10" cavities are precision engineered for restricted tuning range, minimum weight-frequency stability and temperature compensation. The "10" series includes 720 different cavities designed for maximum power and/or voltage ratings of a variety of tubes.

Call or write for engineering drawings and specifications.

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TWX Brookfield, Ill. 2796

CIRCLE READER SERVICE CARD 32

9:30 - 10:00 Radio Frequency Radiation From Hypersonic Plasmas With Impressed Oscillating Electric Fields
C. A. Roberts Douglas

10:00 - 10:15 INTERMISSION

10:15 - 10:45 Propagation of Electromagnetic Waves in a Plasma With An Inhomogeneous Electron Density
A. J. Penico Sylvania

10:45 - 11:15 The Effects of Errors in Rate Constants on Non-Equilibrium Shock Layer Electron Density Calculations
M. H. Bortner G.E.

11:15 - 11:45 Correlation of Telemetry Signal Attenuation Data With the Transition From Free Molecular to Continuum Flow
W. C. King G.E.

11:45 - 12:15 Non-Linear Modeling of Maxwell's Equations
J. E. Belyea, K. M. Siegel Univ. of Michigan

2:15 - 1:30 LUNCH

30 - 4:45
FOURTH TECHNICAL SESSION
Chairman: C. J. Sletten AFCRC

1:30 - 2:00 Radiation and Admittance of a Slotted-Sphere Antenna Surrounded by a Plasma Sheath
J. W. Marini Electromagnetic Research Corp.

2:00 - 2:30 Antenna Breakdown Conditions in the Presence of the Plasma Sheath
R. F. Whitmer Sylvania
A. D. MacDonald Dalehousie Univ.

2:30 - 3:00 Power Handling Capability of Antennas at High Altitudes
T. Morita S.R.I.

3:00 - 3:15 INTERMISSION

3:15 - 3:45 Microwave Breakdown of Antenna Radomes at High Altitudes
P. P. Keenan G.E.

3:45 - 4:15 Interaction of Microwave Radiation With A Non-Uniform Plasma
M. Klein, K. Bruecker, H. Greybar, J. King G.E.

4:15 - 4:45 Experimental Investigation of Plasma Sheath Properties of a Re-Entry Vehicle
W. Rotman, G. Meltz AFCRC

Wednesday 9 December 1959

30 - 11:45
FIFTH TECHNICAL SESSION
Chairman: M. O'Day AFCRC

8:30 - 9:00 Experiments With Plasmas Produced by Alkali-Metal-Seeded-Cyanogen-Oxygen-Flames for Study of Electromagnetic Wave Propagation at the Langley Research Center
P. W. Huber N.A.S.A.

9:00 - 9:30 Microwave Techniques for Hypersonic Ballistic Ranges
R. I. Primich C.A.R.D.E.

9:30 - 10:00 Experimental Investigation of the Interaction of the Plasma Sheath with Electromagnetic Radiation in a Hypersonic Low Density Wind Tunnel
R. L. Chuan Univ. of Southern California

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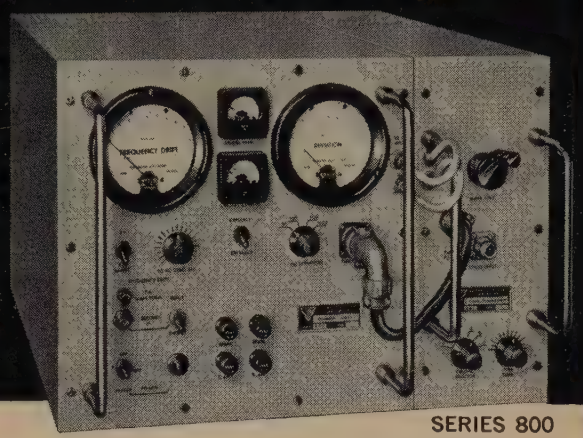
the leader and pioneer in stalos

STALO STABILITY TESTER

Accurate to 1 part in 10^9

A VERSATILE MICROWAVE STABILITY TESTER... DESIGNED FOR ANY APPLICATION REQUIRING PRECISE MEASUREMENT OF FREQUENCY STABILITY.



SERIES 800

Measures long term drift and short term deviation in frequency bands from UHF to 10,000 mc. Checks stability of radar systems components such as stalos, cohos, klystrons and other stable signal sources – either on the production line or in the field. Particularly useful in the design, testing and maintenance of MTI equipped radars.

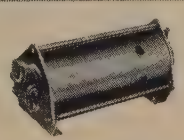
FEATURES:

- Short Term Accuracy: 1 part in 10^9
- Long Term Accuracy: 1 part in 10^6
- Provision for Disturbance Frequency Spectrum Analysis
- Direct Meter Presentation of Frequency Drift and Deviation
- Full MIL Construction and Reliability

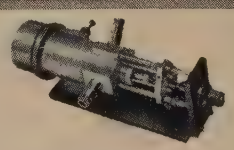
. . . and moderately priced!

Other PITLOG components – Tunable Stalos
Self-contained stable local oscillators used as references for determining the phase or frequency shift of a radar echo. Offer high order of short term stability and high power output.

UHF Tunable Stalo
Frequency Range....300-600 mc
Tuning Range.....10% +
Stability... less than 5 cps peak



L-Band Tunable Stalo
Frequency Range 1000-1500 mc
Tuning Range.....10% +
Stability.....4-8 cps peak



S-Band Tunable Stalo
Frequency Range 2000-3200 mc
Tuning Range.....10% +
Stability.....7-10 cps peak

Write for Bulletin M-2

PITLOG

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237 Lafayette Street New York 12, N. Y.
Advanced Instrumentation Since 1927

CIRCLE READER SERVICE CARD 33

10:00 - 10:15 INTERMISSION

10:15 - 10:45 **On The Change in Radar Cross Section of a Spherical Satellite Caused by a Plasma Sheath**
C. L. Dolph Univ. of Michigan

10:45 - 11:15 **Echo Area of a Plasma Coated Sphere**
L. Peters Jr., R. B. Green Ohio State Univ.

11:15 - 11:45 **The Effect of Doppler Broadening Upon Radar Cross Section of a Plasma Surrounded Body.**
R. E. Kell Cornell Aeronautical Lab.

11:45 - 1:30 Registration for Classified Session and Lunch

1:30 - 4:40
SIXTH TECHNICAL SESSION

Chairman: K. M. Siegel Univ. of Michigan

This Session is Classified "SECRET" and Attendees will need both Security Clearance and Need-To-Know.

1:30 - 2:05 **Ionization Characteristics of Hypersonic Vehicles**
S. Molner Convair

2:05 - 2:40 **Some Measurements of the Physical Properties of the Plasma Sheath Around Hypervelocity Projectiles**
C. J. Maiden, C. St. Pierre C.A.R.D.E.

2:40 - 2:55 INTERMISSION

2:55 - 3:30 **Ionized Wake of Re-Entry Objects**
S. C. Lin Avco

3:30 - 4:05 **Shock Layer Attenuation Data Collected From Missile Tests At the Atlantic Missile Range**
E. M. Fetner R.C.A.

4:05 - 4:40 **Ionization Trail Effects During IRBM Re-Entry**
L. T. Dolphin Jr., Mr. L. Leadabrand S.R.I.

For further information regarding this symposium, interested readers are advised to contact:
Miss Alice Cahill, CRRD
Hqs, A.F. Cambridge Research Center
Laurence G. Hanscom Field
Bedford, Massachusetts.

LITERATURE . . .

WIDE BAND, I-F, TRANSISTORIZED AMPLIFIER AND PRE-AMPLIFIER BROCHURE

Instruments for Industry is now offering a four-page color brochure on their expanded line of wide band, I-F and transistorized amplifiers and pre-amplifiers.

In addition to each model being illustrated, detailed specifications and descriptions are also included. Unit price and quantity discounts are also given.

Instruments for Industry, Inc., are known for their design and manufacture of automatic countermeasures, communications systems and special purpose amplifier systems for industry and the military.

CIRCLE READER SERVICE CARD 112

NEW BULLETIN DESCRIBES VACUUM TUBE GRADE BRAZING ALLOYS

Vacuum Tube Grade brazing alloys ar the subject of Bulletin 25, recently issue by Handy & Harman. The new four-pag bulletin describes the high-purity, low vapo pressure alloys which are required for kly stron and magnetron tubes and comple electronic equipment for commercial an military use. Included in the bulletin i information on temperatures and composi tions of Vacuum Tube Grade brazing al loys, their brazing characteristics in a hy drogen atmosphere and their impurity limits The melting and boiling points and vapo pressures of various metals are outlined o charts.

CIRCLE READER SERVICE CARD 11

● ● ●

NEW FERROTEC CATALOG

Ferrotec, Inc., 217 California Street Newton, Massachusetts, has recently issue a new 4-page short form catalog entitled "Microwave Ferrite Components." Th catalog describes a most comprehensive lin including resonance isolators, circulators switches, tee circulators, phase shifters, an modulators.

In addition, sub-groups of coaxial an test equipment isolators; high power, mini ature and microwave relay isolators; an Faraday rotators and differential phase shif circulators are described. The catalog als provides additional information on specia configurations, and special ferrites for ne design requirements.

CIRCLE READER SERVICE CARD 11

WAVEGUIDE TUBING

formed and bent to close-tolerance specifications

KENT EXPERIENCE in forming waveguides to precise requirements dates back to the pioneering days of micro wave. **KENT QUALITY** is attested by the dozens of leading makers of high-performance equipment who entrust thei most complex forming-bending problems to Kent engineers. **KENT FACILITIES** — largest in the country for vol ume-production runs — are also geared to the development of prototypes. **KENT COSTS** are often lower because a exceptional stock of waveguide bending and forming tools eliminates special tooling charges on many jobs. And **KENT QUOTATIONS** are dependably prompt.

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F. C. KENT CORPORATION

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CIRCLE READER SERVICE CARD 34

New from Japan . . .

Important advance in short-haul, multi-channel communications

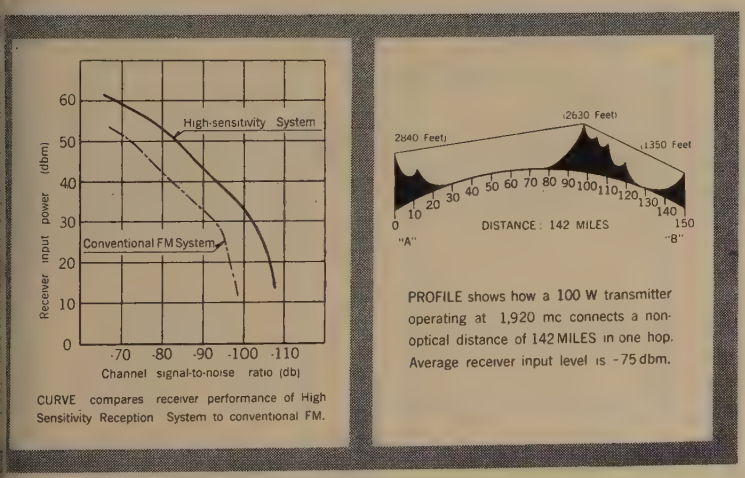
Microwave 60-channel voice transmission over a non-optical path up to 300 MILES is now possible without repeater stations.

NEC's High Sensitivity Reception System, by extending threshold level and improving S/N ratio 10 to 13 db, makes this hop with only 1/20 of the power output required for conventional systems.

A 100 W transmitter in the 1,800-mc band, for example, has a scatter path of 100—150 MILES. A conventional FM system requires 2 KW output and at least one repeater station to connect the same distance over a non-optical path.

By eliminating high-power amplifiers and repeater stations, the High Sensitivity Reception System results in considerable reduction in initial investment. Savings in maintenance and power consumption are estimated at 40% or more.

Extensive propagation tests have been made, and NEC is now prepared to supply commercial users and government agencies anywhere in the world. Please write for detailed information.

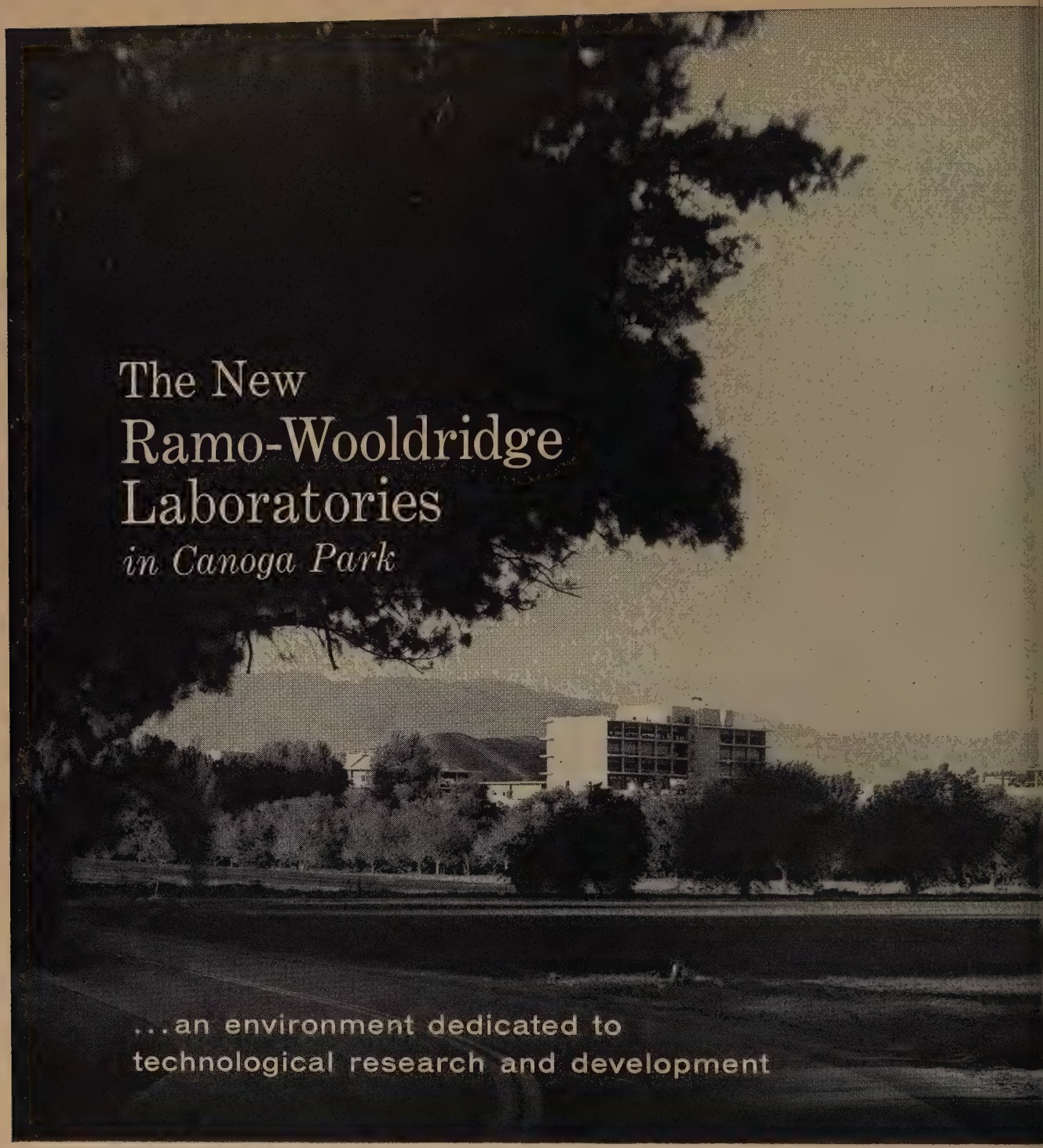


CURVE compares receiver performance of High Sensitivity Reception System to conventional FM.

PROFILE shows how a 100 W transmitter operating at 1,920 mc connects a non-optical distance of 142 MILES in one hop. Average receiver input level is -75 dbm.

NEC *Nippon Electric Company Ltd.*
Tokyo, Japan
Electronics / Communications Systems

CIRCLE READER SERVICE CARD 35



The new Ramo-Wooldridge Laboratories in Canoga Park, California, will provide an excellent environment for scientists and engineers engaged in technological research and development. Because of the high degree of scientific and engineering effort involved in Ramo-Wooldridge programs, technically trained people are assigned a more dominant role in the management of the organization than is customary.

The ninety-acre landscaped site, with modern buildings grouped around a central mall, contributes to the academic environment necessary for creative work. The new Laboratories will be the West Coast headquarters of Thompson Ramo Wooldridge Inc. as well as house the Ramo-Wooldridge division of TRW.

The Ramo-Wooldridge Laboratories are engaged in the broad fields of electronic systems technology, computers, and data processing. Outstanding opportunities exist for scientists and engineers.

For specific information on current openings write to Mr. D. L. Pyke.

THE RAMO-WOOLDRIDGE LABORATORIES

8433 FALLBROOK AVENUE, CANOGA PARK, CALIFORNIA

SCIENTIFIC-ATLANTA, INC.
Atlanta, Georgia

BOX SCORE

NAME: Scientific-Atlanta, Inc.

LOCATION: 2162 Piedmont Road, N.E., Atlanta 9, Georgia

PRODUCTS: Instruments for antenna pattern ranges including polar and rectangular recorders, receivers, antenna positioners and towers, signal sources, transmitting and standard gain antennas, and microwave components. Other activities include contract research and development and plastic parts for missiles.

HIGHLIGHTS: By concentrating its efforts in a narrow but expanding field, Scientific-Atlanta, Inc. has established itself as the leading designer and manufacturer of antenna test instruments. Sales and profits have doubled each year for the past five years. Growth has been financed equally by retained earnings and investments principally by employees and management. New products are continually being added to the product line as the result of an active research and development program.

STATISTICS: June 30, 1959

Fiscal year 1959 sales: $1,387,022

Number of employees: 112

Plant size: 20,000 square feet

History

SCIENTIFIC-ATLANTA, INC. was incorporated in August 1951 under the name "Scientific Associates, Inc,". The name was subsequently changed to Scientific-Atlanta, Inc. after learning of a conflict with another group having a prior claim to this name. Six members of the staff of the Georgia Tech Engineering Experiment Station formed the company for the purpose of providing an electronics manufacturing facility in the Southeast but with a special interest in developing and manufacturing microwave antennas. The company actually began business in August 1952 after receiving a contract for developing a rapid scanning radar antenna from Yale University.

The first three years were spent in performing several small industrial and military contracts in both electronic instruments and microwave antennas. The total sales for the three-year period was $135,000 with a profit of $3,000. The number of full-time employees had reached 10. But most important, an antenna pattern recorder had been developed which became the first catalog product and which set the course for future growth.

Development of this new antenna pattern recorder had begun a year earlier when Scientific-Atlanta needed a recorder for its own use. Two other companies learned of this work and placed orders on the basis of specifications and preliminary drawings. The first recorder was hand delivered but before reaching its destination it was shown to eight prospective customers. The response was so good that four placed orders within two months and all eight placed orders in less than a year. The rapid acceptance of the recorder encouraged the company to expand and build its own initial 5,000 square-foot building at its present lo-

ientific-Atlanta officers (l. to r.) William H. Bradley, Glen P. Robinson, Jr., J. Searcy Hollis and William L. Davenport, Jr.

cation in August 1955. This was the beginning of a steady and solid growth.

The success of the rectangular antenna pattern recorder brought about the development of a polar recorder and a few related antenna test instruments. An attempt was made to broaden the recorder line by developing a digital X-Y plotter but it was soon found more desirable to expand initially in depth rather than in breadth. The X-Y plotter required a specialized knowledge of the digital computer field and a completely different type of selling effort. This activity was just recently turned over to the Gerber Scientific Instrument Company so that Scientific-Atlanta could concentrate its efforts in the antenna test instrumentation field.

Development of a superheterodyne receiving system especially designed for antenna test ranges was begun in June 1957. Again, orders were received for several of these instruments before the final design had been completed. Three production receivers were delivered in less than seven months after the original concept and more than sixty receivers have been shipped since January 1958.

Scientific-Atlanta was still missing too many sales, especially when it came to providing complete antenna test facilities. A further expansion in personnel and facilities accelerated the development of a line of antenna positioners, model range towers, control and indicator units, and pattern integrators. In the past fiscal year a line of transmitting and standard gain antennas, signal sources, transmitting towers, and a Fourier computer were developed and are being produced.

The production of model range towers and a venture into the production of dielectric Luneberg lenses required the services of plastics technicians and a plastics laboratory. This led to the production of glass-reinforced plastic parts for aircraft, missiles, and industry. The plastics division now accounts for approximately 10% of the company's sales.

Scientific Sales Engineering Company was incorporate in July 1958 as a wholly-owned subsidiary of Scientifi Atlanta, Inc. Its purpose was to serve as sales represent tive for several leading electronic manufacturers includin the parent company. Its territory covers the southeaster states and it now has offices in North Carolina, Florid Alabama, and Georgia.

Financial

The initial capitalization of Scientific-Atlanta was $60 Small sales of stock were made yearly to employe and associates, and earnings were retained in the busines Approximately half of the net assets of $330,000 at Jun 30, 1959 was provided by retained earnings.

The company has maintained a profit level of 5% o sales, and during the last four years of the rapid growt period has consistently earned approximately 20% on i vested capital. About 60% of the net assets is invested i plant facilities and production and research equipmen Bank credit attracted by the growth pattern of the com pany has provided working capital to meet the growth re quirements.

The company has only common stock outstanding, an its 214,000 shares are held by about 200 stockholders. Th stock is currently traded over-the-counter by several Atlant brokerage firms at approximately $10.00 a share, about 3 times earning reported last year, adjusted for a 50% stock dividend distributed in August 1959.

Personnel

Glen Robinson joined Scientific-Atlanta as general ma ager and sole part-time employee in April 1952. His in tial investment of $100 made him the seventh stockhold in a $700 corporation. He was elected president in Noven ber 1952 and served as the engineer, salesman, bookkeepe machinist, and technician. He studied chemical enginee ing at Georgia Tech until he joined the Signal Corps durin World War II. His military experience included trainin

Electronics Assembly Area.

ill Shore, Director of the Plastics Division, is shown third from right inspecting a section of a Model Range Tower.

a radio-teletype officer and duties as post signal officer several bases in the Pacific area. He returned to Georgia ech where he received B.S. and M.S. degrees in Physics id worked part time at the Engineering Experiment Sta- on. He worked at the Oak Ridge National Laboratory om 1950 until he joined Scientific-Atlanta.

S. F. Hutchins joined the company in April 1956 as e first full-time mechanical engineer. "Ted" spent eleven ars in the U. S. Navy before returning to Georgia Tech complete his work for a degree in mechanical engineer- g which he had begun in 1938. Ted now directs the ac- vities of the mechanical design group of six mechanical gineers and eight draftsmen and the mechanical produc- on group of approximately 32 machinists and assembly rsonnel.

Charles H. Currie first became interested in Scientific- tlanta in 1955 as a part-time engineer. In December)57 he joined the company full time as the chief elec- onics engineer. Before entering Georgia Tech in 1949, harlie spent six years in the Air Force in ground radar stem instruction, maintenance and development. He re- ived B.S. and M.S. degrees in electrical engineering and orked at the Georgia Tech Engineering Experiment Sta- on while attending school. Charlie directs the activities five electronic engineers and approximately forty tech- cians and production personnel.

William H. Bradley joined the Scientific-Atlanta staff June 1957 as sales manager, and was elected Vice Presi- ent — Marketing in August 1958. Bill has a broad back- ound in practical radar and electronics work in the Signal orps and on the staff of the Georgia Tech Engineering xperiment Station. He joined an electronic manufacturer's presentative company in 1952 where he gained valua- e experience and a good reputation in electronic instru- ent sales. After joining Scientific-Atlanta, Bill immedi- ely began to develop an outstanding sales organization hich now consists of ten of the leading national manu- cturer's representatives, an export representative, and a nadian representative. Bill is also President of Scien- ic Sales Engineering Company and directs the activities four sales engineers covering eight southeastern states.

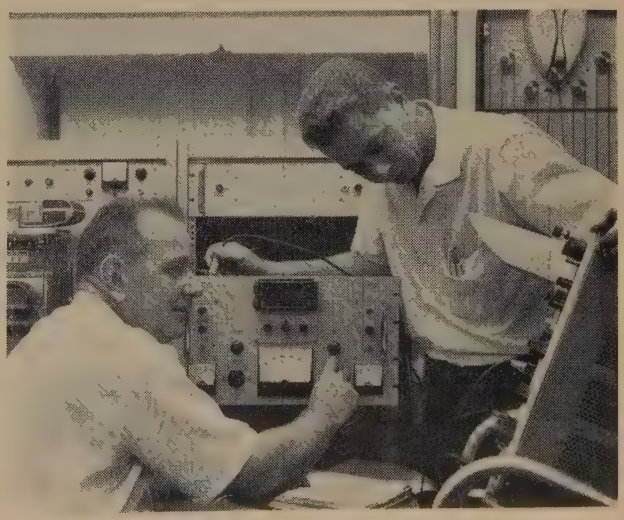
Larry Clayton was employed as a part-time research phy- ist in February 1957 and later joined the company full ne as director of electronics research and development. rry received B.S. and M.S. degrees in Physics at Georgia Tech and will receive his Ph.D. degree upon completion of a thesis in microwave spectroscopy. He worked at the Georgia Tech Engineering Experiment Station on several radar and electronics development contracts from 1950 until he joined Scientific-Atlanta.

Searcy Hollis first became interested in Scientific-Atlanta in the fall of 1954 when he was engaged as a consulting engineer while working at Georgia Tech. He was elected to the board of directors in 1956 and joined the company full time in February 1959 as Director of Engineering. In April 1959 he was elected Vice President — Engineering. Searcy entered Georgia Tech in 1947 after several years experience in electronics in civil service and a tour of duty in the U.S. Navy. He received the degrees of B.E.E. with highest honor and M.S. in E.E. from Georgia Tech. Searcy is author of a handbook on "Antenna Measurements" which has been recognized as a basic text in this field and which has been distributed to key technical personnel throughout the world.

William L. Davenport, Jr. has served as Vice President — Finance and Secretary-Treasurer since February 1959. Prior to joining Scientific-Atlanta, Bill Davenport had been with The Coca Cola Company for ten years, during the last four of which he served as Budget Director of that firm. Bill is a graduate of Harvard Business School, having completed work for his M.B.A. after finishing undergraduate work at Southern Methodist University and serving four years in the Navy. Like many others in the company, Bill Davenport became interested in the company as a stockholder and part-time consultant. He has served as a member of the board of directors since 1957; and up to the time of joining the company full time, worked nights and on weekends on accounting and administrative problems. He is presently responsible for all financial and administrative matters of the company.

Scientific-Atlanta now has 120 employees, 25 of which are graduate engineers. Employee turnover is extremely low and the company plans to keep it that way by providing the best possible employee benefits within its means. An attractive profit sharing plan and a stock purchase plan are only two of many benefits offered to all employees.

An antenna test console is being checked out by Charles H. Currie and Hugo R. Fulmer.



AEL® INC.

THE LEADER IN...

CRYSTAL VIDEO DETECTION

CRYSTAL VIDEO DETECTOR MOUNTS

that can more than triple the range of existing microwave beacons and provide countermeasure systems with tangential sensitivities as high as —65 dbm. Available with standard brass connectors and bodies ... or aluminum for LIGHTWEIGHT applications. (available with type N, TNC, Miniature, and BNC connectors).

Mounts available from 50 Mc/s to 12 KMC in continuous or octave bands in coaxial configuration. Higher frequencies in waveguide.

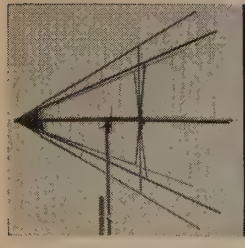
REDUCE SYSTEM POWER DRAIN • CUT WEIGHT
CUT COST • EXTEND DETECTION RANGE

TRANSISTORIZED VIDEO AMPLIFIERS
for Crystal Video Detection

Transistorized or hard-tube crystal video receiver amplifiers designed with high input impedance to prevent crystal detector loading. Other features include ... low equivalent noise, high gain, crystal bias circuits, small size and LIGHT WEIGHT. Several "standard" models available or units built to your specifications.

AND

BROADBAND ANTENNAS



AEL's Broadband circularly polarized conical helix antenna, matched over greater than 10 to 1 frequency bands, is ideally suited for countermeasures and telemetering applications. The teardrop pattern, of essentially constant beamwidth, provides a unique broadband, circularly polarized feed antenna for parabolic reflectors.

Frequencies from 40 Mc/s to 8000 Mc/s

AEL has built VHF-TV Slotted Cylinders, Air Inflated Monopoles, Discones, Horns, Airborne Blade and many other antennas. For solutions to your antenna problems contact AEL for the services of a highly skilled team of antenna design engineers working in our modern high frequency and microwave laboratories at AEL's 50 acre tract in Colmar Penna.

Investigate the opportunities at AEL for creative engineers

AEL AMERICAN ELECTRONIC LABORATORIES, INCORPORATED
121 N. 7th ST., PHILADELPHIA 6, PENNA.

In Canada contact: Conway Electronic Enterprises Regd., Toronto, Canada

CIRCLE READER SERVICE CARD 36

ALL SIZES
MS FLANGES
IN STOCK

THE FINEST QUALITY BRASS AND ALUMINUM STANDARD WAVEGUIDE FLANGES in stock at Formcraft—all precision made to military standards. For rigid and flexible waveguides.

Special flanges to your specifications. Send sketch or blueprint for a quotation.

SEND FOR NEW BROCHURE #14B
DESCRIBING AND ILLUSTRATING ALL THE STOCK FLANGES

Formcraft TOOL CO

2465 S. Archer Ave. • Chicago 16, Ill. • CAlumet 5-317

CIRCLE READER SERVICE CARD 37

(*Continued from page 59*)

Facilities

The company owns its own buildings on two acres of land within five minutes from the heart of Atlanta. The present total floor space of 20,000 square feet consists of 1,500 feet of administrative offices, 3,000 in engineering with the remainder in use for electronic, mechanical, and plastics production.

Facilities are maintained for all types of engineering and production services required in the company's operation except for large machining and foundry work. The company maintains an antenna test range and a microwave laboratory in addition to the normal development laboratories and production shops. The company has recently purchased a sixty-five acre tract of land on the outskirts of Atlanta and plans to build new facilities soon.

Future

We are proud of our growth record even though by many standards it may appear to be slow. We have resisted the temptation to expand in all directions and to build up a larger backlog to try to insure future sales. We realize that our course of sound and orderly growth can only be by providing increasingly better designed equipment on reasonable and dependable delivery schedules.

Sales for the current year are expected to reach 2 million dollars. An annual sales level of 10 million dollars is set as a goal for 1963. This goal will be reached not by an expanding market but by broadening our present product line to include other phases of microwave instrumentation and by adapting our instruments to other fields such as optics and sound.

TERATURE . . .

WIDE RANGE SPECTRUM ANALYZERS CATALOG DIGEST

The most complete line of automatic ctrum analyzers with 0.5 cps-44 kmc ge, unique response curve tracers, and neering new instrumentation systems are cribed in the new Catalog Digest pub- ied by Panoramic Radio Products, Inc., 4 So. Fulton Avenue, Mount Vernon, Y. Ranging from compact low cost ipment to all-inclusive special purpose tems, these Panoramic instruments find ad application in vibration and noise dies, FM/FM telemetry systems, LF ough K-band spectrum analysis, single eband studies, response tracing of net- rks, and many other fields.

For the reader's convenience, the new alog Digest groups specifications and criptions under several distinct head- s: Spectrum analyzers, Special purpose truments, Accessory instruments, Trac- systems, Single sideband analyzers, RF- IF-UHF and Microwave analyzers, and emetering spectrum analyzers and cali- tors.

RCLE READER SERVICE CARD 115

NEW PRODUCTS

REQUENCY RANGE OF TELONIC SWEEP GENERATORS DOUBLED BY NEW INSTRUMENTS

The frequency range of Telonic Sweep nerators has been doubled by the addi- n of four new instruments to the line. nufactured by Telonic Industries, Inc., ech Grove, the Sweep Generators are dely used in the laboratory and on the duction line to measure the frequency ponse of electronic circuits.

The four instruments extend the range ered by Telonic Sweep Generators up a new limit of 2320 mc. The center quency of the new Model SP-99 can be ed over the range 1400 to 1900 mc, an portant new telemetering band. The del SP-100 covers the range from 1000 1500 mc; the Model SP-101, from 1500 2000 mc; the Model SP-102, from 1700 2300 mc. In each case, the sweep width be varied from 100 mc down to .25

Sweep rate of the new instruments is line frequency, 50 or 60 cps. The sweep oscillator is off during the retrace half of the cycle, providing a zero-base line for accurate evaluation of the oscilloscope image. Power output is approximately one volt, peak to peak, into 50 ohms. A 0-10 db vernier attenuator is provided for precise adjustment of the output voltage.

CIRCLE READER SERVICE CARD 116

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G-R SECONDARY FREQUENCY STANDARD

A compact, crystal-controlled Time/Frequency Calibrator (Type 1213-D), with a short-time stability of 1 part in 10^7, which furnishes standard frequencies from 10 kc to 1000 Mc not only for the calibration of electronic equipment, such as oscillators, receivers and transmitters, but also for the measurement of unknown frequencies, has been developed by the General Radio Company, West Concord, Mass. The instrument also provides timing markers at decade intervals from 0.1 to 100 microseconds.

An internal crystal oscillator — using a 5-Mc AT-cut hermetically-sealed quartz plate — is electron coupled to a 2:1 multiplier, followed by a 10-Mc buffer stage which drives a series of multivibrators with fundamentals of 1 Mc, 100 and 10 kc. Generated harmonics can be mixed with an incoming signal in the internal crystal mixer or fed to other equipment through a coaxial (50-ohm) line. Audio amplification is provided for the beat frequencies thus produced, and video amplification is available for the timing-marker signals.

Another feature is a narrow-range frequency adjustment for setting of the crystal oscillator to zero beat with standard-frequency transmissions or other external standards. Also, there is a touch-button deviator to introduce a small frequency decrease to establish "sense" in indications near zero-beat.

When standardized against standard-frequency radio transmissions, such as those broadcast by Station WWV, the calibrator affords all of the functions of an accurate standard of frequency.

Housed in a standard G-R Unit Instrument cabinet, the calibrator is 14½" x 5¾" x 7" overall, including a 1203-B Unit Power Supply.

Price of the Type 1213-D Calibrator is $315.00, and the 1203-B Unit Power Supply, $40.00; both net and f.o.b., West Concord, Mass.

CIRCLE READER SERVICE CARD 117

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FIRST COMPLETE QDS CONNECTOR LINE

Availability of the first and only complete line of QDS connectors has been announced by the Gremar Manufacturing Company, Inc., Wakefield, Mass. Gremar QDS connectors are weatherproof, quick-disconnect types designed for use with medium size coaxial cables. They employ a three ball positive-locking

(*Continued on page 64*)

WEINSCHEL

COAXIAL TERMINATIONS

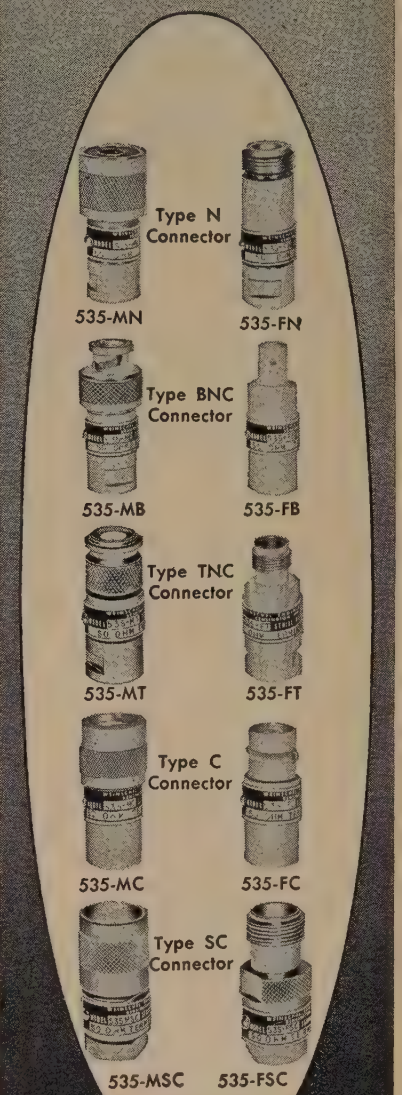
DC to 10 KMC

50 ohms

Connectors: N, C, SC, BNC and TNC

Individual VSWR calibrations supplied at seven frequencies: DC, .4, 1, 2, 4, 7.5 and 10 KMC.

Made with Weinschel Film Resistors for maximum stability.



WE CO

Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12.4 KMC. Write for complete catalog.

Weinschel Engineering

KENSINGTON, MARYLAND

CIRCLE READER SERVICE CARD 38

Diamond can offer the solution to your rotary joint problems — waveguide or coaxial . . . high power . . . inline . . . broadband . . . multi-channel — whatever they may be.

WAVEGUIDE IN-LINE ROTARY JOINTS

DIC NO.	W.G. SIZE	FREQUENCY KMC/S	VSWR (Max)	INSERTION LOSS (Max)	"WOW" (Max)	POWER HANDLING Peak	Average
445*	3 × 1½	2.6–3.95	1.5 : 1	0.1 db	.05 db	370 KW	3 KW
545*	2 × 1	3.95–5.85	1.5 : 1	0.1 db	.05 db	160 KW	2 KW
645*	1½ × ¾	5.85–8.2	1.5 : 1	0.1 db	.05 db	73 KW	1 KW
845*	1 × ½	8.2–12.4	1.5 : 1	0.1 db	.05 db	37 KW	1 KW
945*	.702 × .391	12.4–18.0	1.5 : 1	0.1 db	.05 db	16 KW	1 KW
1045*	½ × ¼	18.0–26.5	1.5 : 1	0.1 db	.05 db	8 KW	½ KW
1145*	.360 × .220	26.5–40.0	1.5 : 1	0.1 db	.05 db	3 KW	½ KW

* Patents applied for.

SINGLE CHANNEL COAXIAL ROTARY JOINTS

DIC NO.	LINE SIZE	FREQUENCY MC/S	VSWR (Max)	INSERTION LOSS	"WOW" (Max)
2045	6⅛	100–140	1.15 : 1.0	Negligible	0.5 db
2046	6⅛ (75 ohm)	400–700	1.2 : 1.0	Negligible	.05 db
2047	3⅛	200–400	1.2 : 1.0	Negligible	.05 db
2048	3⅛	400–600	1.1 : 1.0	Negligible	.05 db
2049	⅞	400–450	1.1 : 1.0	Negligible	.05 db
2049-2	⅞ (46.5 ohm)	2170–2320	1.15 : 1.0	Negligible	.05 db
2049-3	Type N	200–300	1.5 : 1.0	Negligible	.05 db
2050	1⅝	2100–2400	1.15 : 1.0	Negligible	.05 db
2400-1	⅜	4–15 kmc /s	1.8 : 1.0	Negligible	.05 db

DUAL CHANNEL COAXIAL ROTARY JOINTS

DIC NO.	CHANNEL	LINE SIZE	FREQUENCY MC/S	VSWR (Max)	INSERTION LOSS	"WOW" (Max)
2246	Main Auxiliary	6⅛ 3⅛	380–440 380–440	1.15 : 1.0 1.2 : 1.0	Negligible Negligible	.05 db .05 db
2247	Main Auxiliary	6⅛ Type N	415–455 I.F.F.	1.15 : 1.0 1.2 : 1.0	Negligible Negligible	.05 db .05 db
2248	Main Auxiliary	3⅛ 3⅛	785–815 785–815	1.1 : 1.0 1.15 : 1.0	Negligible Negligible	.05 db .05 db
2249-1	Main Auxiliary	⅞ BNC	2170–2320 30	1.1 : 1.0 1.1 : 1.0	Negligible Negligible	.05 db .05 db
2249-2	Main Auxiliary	Type N BNC	2150–2350 30	1.15 : 1.0 1.1 : 1.0	Negligible Negligible	.05 db .05 db
2250	Main Auxiliary	⅞ ⅞	215–260 215–260	1.1 : 1.0 1.25 : 1.0	Negligible Negligible	.05 db .05 db

DIAMOND
DICO ANTENNA & MICROWAVE
CORPORATION
River Street • Winchester, Mass.

EWEN-KNIGHT DEDICATION

More than three hundred guests attended official dedicat ceremonies, on Sept. 29, of the Ewen-Knight Corporation's n installation at Cerel-Perini's East Natick, Mass., Industrial Pa

Aladdin, a living counterpart of the firm's trademark, sy bolizing their motto "At the Frontiers of Electronics," gree prominent members of the electronics industry, the press, ra and television media, and representatives of the financial fie

At the formal ceremony, Martin Cerel, President of Cer Perini Associates, Inc., presented an inscribed scroll to I Harold I. Ewen, President and Technical Director of Ew Knight, and welcomed the firm to Cerel-Perini's family "model plants for industries on the grow."

In addition to Dr. Ewen, other officials of the firm we present to explain the production facilities. They includ Leo F. Mulhern, Vice-President and Clerk; Robert H. Farwe Vice-President and Director of Sales; and key technical m such as Hays Penfield, Dr. Peter A. Rizzi, Edwin W. Richt John A. Campbell and Joseph F. Wenckus.

The Ewen-Knight Corporation, founded by Dr. Ewen and corporated in 1952, was established for the purpose of resear and development in electronics and radio astronomy. T company's record of accomplishment includes, for example, t first commercially available DC comparison radiometer, 19 the first radiometer with a sensitivity of 1/400,000 which capable of detecting microwave radiation levels 40,000 tim lower than the average microwave radiation of earth, t first detection of radio frequency from the planet Saturn, 19 the first 800 megacycle "gain-bandwidth" product masers X band, 1958; and the first commercially available gain-mc ulated switched load radiometers to detect weak signals.

Over the past seven years, Ewen-Knight has experienced steady growth and it was for this reason primarily that t decision was made to relocate in a modern plant, tailored suit its needs. Cerel-Perini's East Natick Industrial Park w chosen also for its prime location, being close to Route 9, t Massachusetts Turnpike and Route 30, and for its proxim to the Boston technological institutions.

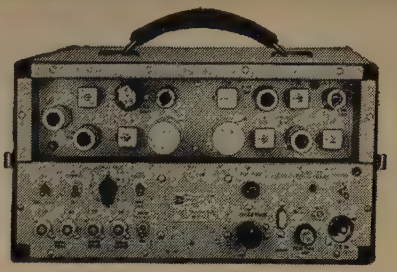
• • •

ON THE JOB INSPECTION

Irving M. Gross (left), president of the Portchester instr ment Corporation of Port Chester, N.Y., is shown inspecti a waveguide filter and mixer assembly, which is manufactur by his firm, during a recent visit to Philco Corporation's G ernment & Industrial division plant in Philadelphia. Discussi the operating capabilities of the microwave component as it used in Philco's 2000 mc tropospheric scatter communicatio receiver is Vito Moreno, a senior electrical engineer in t scatter communications engineering lab.

1003-C VIDEO TRANSMISSION TEST SIGNAL GENERATOR

Produces multi-frequency burst, stairstep, modulated stairstep, white window, composite sync. Variable duty cycle. Regulated power supply.



1004-B VIDEO TRANSMISSION TEST SIGNAL RECEIVER

Very rapid and accurate measurements of differential phase and differential gain characteristics of video facilities. Responds to standard stairstep test signal modulated with 3.58mc, or any differential phase or gain test signal.

VIDEO TRANSMISSION TEST EQUIPMENT

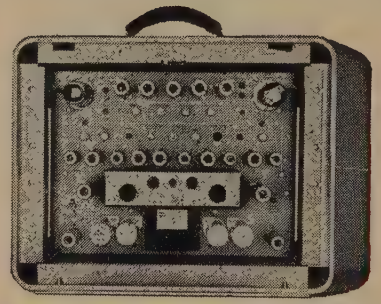
In Daily Use by All Major Networks, Stations and Telephone Co. Coaxial Cable, Microwave, and Intercity Facilities.

ALL CARRYING CASE UNITS IMMEDIATELY ADAPTABLE TO STANDARD RACK MOUNTING

1005-A VIDEO TRANSMISSION TEST SET

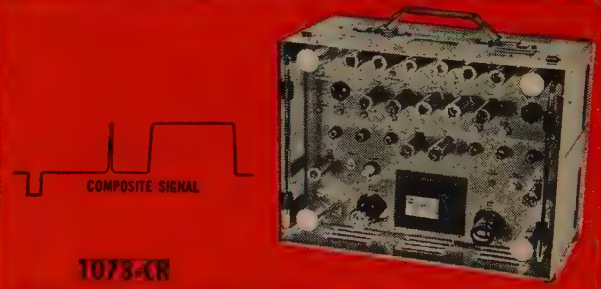
1005-A1 — Produces composite television waveforms suitable for measuring amplitude vs. frequency; differential gain vs. amplitude; dynamic linearity; differential phase vs. amplitude; high frequency transient response; low frequency transient response; low frequency phase or streaking, smears, mismatches; and other video characteristics.

1005-A2 — Supplies composite EIA Sync, blanking, horizontal and vertical drive signals and regulated B + power for itself and 1005-A1. Features magnetic core binary counters.



1008-A VERTICAL INTERVAL KEYER

Permits test and control signals to be transmitted simultaneously with program material, between frames of TV picture. Any test signal (multiburst, stairstep, color bar, etc.) may be added to the composite program signal. Test signals are always present for checking transmission conditions without impairing picture quality. The home viewer is not aware of their presence.



1073-CR

SINE SQUARED (SIN^2) — SQUARE WAVE GENERATOR

Produces new waveform for testing TV or other pulse unit or system for amplitude and phase characteristics. Sin^2—Square Wave pulse is equivalent to TV camera signal and is more sensitive than a Square Wave in indicating ringing. Video test signal adjustable for 1.0 volts or 1.4 volts peak to peak. Now in use by major TV networks and telephone companies.

AT THE FRONTIERS OF ELECTRONICS
COLOR TV · INDUSTRIAL INSTRUMENTATION · TELEMETRY

TELECHROME MANUFACTURING CORP.

Full Specifications & Details Available on Request

TELECHROME MANUFACTURING CORP.

28 RANICK DRIVE AMITYVILLE, N.Y. Lincoln 1-3600 Cable Address: COLORTV TWX: AMITYVILLE NY2314

Midwest Engineering Division — 105 W. St. Charles Rd., Lombard, Ill., MAyfair 7-5026 Western Engineering Division — 13635 Victory Blvd., Van Nuys, Calif., State 2-7479

NEW
UNIVERSAL KLYSTRON POWER SUPPLY

We call it the PRD Type 812...you'll call it the answer to all your klystron power supply problems.

This completely new unit consists of four, separate, regulated supplies: beam, reflector, grid, and heater . . . *and* combines digital read-out of beam and reflector voltages *plus* outputs for operating two klystron tubes simultaneously.

PLUS a special feature for the prevention-of-cruelty to klystrons: The grid and reflector modulation voltages are *clamped* to the cw level in square wave or pulse operation.

The Type 812 also features superior regulation to reduce ripple and noise to an all-time low. Clean modulation characteristics assure a rise and decay time which will not exceed 2 microseconds.

You also get the following full set of PRD extras:

- digital read-out for beam and reflector voltages
- dual outputs for simultaneous operation of two klystrons
- front-panel-check calibration of grid and reflector voltages
- multirange overload protection for beam current
- safety lock when transferring from + to − grid voltage
- external triggering of internal pulse generator

Write for complete data.

POLYTECHNIC RESEARCH & DEVELOPMENT CO., INC.
Factory & General Office:
202 Tillary St., Brooklyn 1, N.Y.
ULster 2-6800
Western Sales Office:
2639 So. La Cienega Blvd., Los Angeles 34, Calif.
UPton 0-1940

(*Continued from page 61*)

coupling and feature the latest type of metal-to-metal cable clamping construction. These connectors have a nominal characteristic impedance of 50 ohms, a peak operating voltage of 1,000 volts, and may be used at frequencies up to 10,000 mcs. All Gremar QDS connectors and adapters have Teflon insulation. Armor clamps are incorporated or standard clamping hardware is available for use with unarmored cables. All Gremar QDS connectors and adapters are manufactured in accordance with applicable paragraphs of specification MIL-C-18867 (Navy) under a rigid quality control program maintained in accordance with specifications MIL-Q-5923C and the new MIL-Q-9858. For specifications of complete line, write for Bulletin No. 7.

CIRCLE READER SERVICE CARD 118

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KEEP ALIVE SUPPLY

Bomac Laboratories, Inc., Salem Road, Beverly, has recently announced a new keep-alive supply — the BL-N-004. It is capable of supplying 170 microamperes at

750 vdc from a 28 vdc source. The output voltage variation is held to ± 3% when the input voltage is varied between 22 and 34 volts. The output current is limited by a self-contained 4.7 megohm resistor. Both the input and the output terminals are isolated from the case. Physical dimensions are 5″ L x 2″ W x 1⅛″ H.

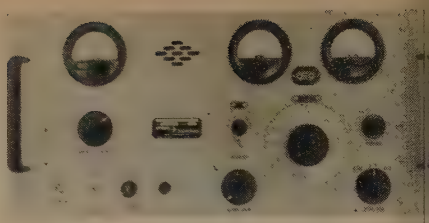
CIRCLE READER SERVICE CARD 119

• • •

NEW TELEMETRY RECEIVER PROVIDES UNUSUAL VERSATILITY FEATURES

A new Telemetry Receiver, Type 11B1, has just been introduced by the Silver Spring, Maryland, Division of General Electronic Laboratories, Inc. This new receiver was designed specifically for use in FM/FM, PDM/FM, and PCM/FM systems. Noise figures of less than 7 db are obtained over the entire band from 215 to 265 megacycles. Other features of the Type 11B1 include reduced intermodulation and interference and increased linear operating range.

A degree of versatility heretofore un-



obtainable in any other telemetry receive is provided for in the Type 11B1. Th user can select either crystal-controlled c continuously-tunable (VFO) modes c operation by simply positioning a switc on the front panel. In the crystal pos tion the tuning dial is set to frequenc and a crystal plugged into the front pane socket. In VFO position the receiver ca be tuned using the main tuning dial. Wit either mode of operation a vernier fre quency adjustment is provided to com pensate for frequency inaccuracies o drift.

The user can also select the optimun bandwidth for his particular telemetr application through the use of plug-i second IF amplifiers with bandwidths c 100, 300, 500 and 750 kilocycles (stanc ard). Other bandwidths, special respons characteristics, etc., are available on spe cial order.

The Type 11B1 Telemetry Receive weighs approximately 48 lbs., measure 8¾″ x 19″ x 15″ and mounts in a stanc ard RETMA relay rack. Power require ments are 115 volts AC, 60 cycles.

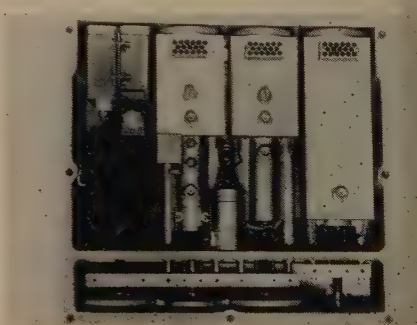
CIRCLE READER SERVICE CARD 12

• • •

NEW STALO DRIVER IS HIGH LEVEL POWER SOURCE

BJ Electronics, Borg-Warner Corp Santa Ana, California, has developed new Stalo Exciter Driver for application where 5 to 10 watts CW or pulsed R are required over S-band.

The Model 86 provides a Stable fre quency power source in radar systems o may be used as a klystron driver source It consists of an L-band cavity oscillato cavity doubler to S-band, and a cavit RF amplifier. The amplifier stage may b



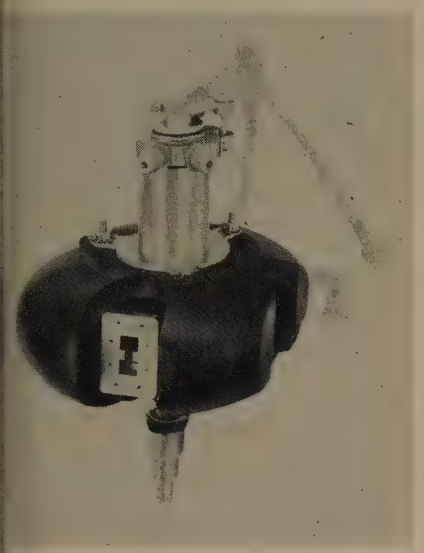
pulsed at any repetition rate. The Mod 86 is completely described in a new bu letin just issued and which is availab upon request.

CIRCLE READER SERVICE CARD 1

BARRATRON

A powerful new ECM weapon, the Litton Industries Barratron tube, was introduced recently.

The new tube, a high power transmitting, self-modulating noise generator, is a proprietary product of Litton's Electron Tube Division. It is available in either tunable or fixed tuned versions, both self-generators of broadband white noise.



Now installed in most ECM systems are CW magnetrons. While this is a relatively compact device, the tunable Barratron tube requires no modulator or noise generator chassis, and the fixed tuned version requires no tuning circuitry or modulator. The result is an even more compact ECM weapon, particularly suited to airborne applications where space is critical.

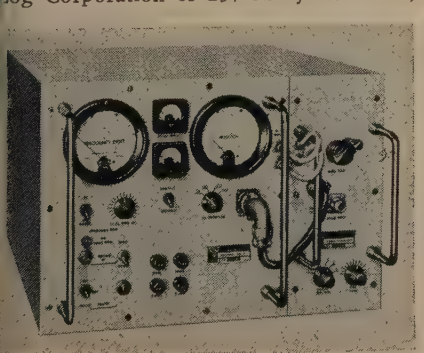
The biggest advantage of the Barratron tube over the magnetron is the former's jamming signal quality, which makes it ten times more effective than the magnetron. The tunable version is a simple replacement for existing ECM systems using tunable magnetrons, and the fixed tuned model is designed primarily for new equipment. Both versions of the tube may be used in either spot or barrage jammers.

CIRCLE READER SERVICE CARD 122

• • •

NEW MICROWAVE STABILITY TESTER AVAILABLE

A new, multi-band, microwave stability tester is now being produced by Pitometer Log Corporation of 237 Lafayette Street, N. Y. C. — manufacturers of radar components and test equipment. The PITLOG Series 800 Stalo Tester, as the apparatus is called is designed for use in any application where a precise measurement of frequency stability is required.



Offering unusual accuracy and versatility, this equipment measures long term drift and short term deviation in frequency bands between 1100 mc to 10,000 mc, and its primary purpose is to check the stability of radar systems components such as stalos, cohos, klystrons and other signal sources . . . either on the production line or in the field. Other applications include troubleshooting of Moving Target Indicator radar systems; isolating sources of frequency disturbance; maser and parametric amplifier evaluation; radio astronomy.

PITLOG Series 800 Stalo Tester comprises two main sub-assemblies, one fixed and one interchangeable. An indicator unit, Model 800, houses the measuring circuitry and power supplies, and the two interchangeable units, Models 801 and 802, are used to heterodyne the signal down to the input range of the indicator. The interchangeable sub-assemblies contain the heads for a given frequency band. Model 801 covers L/S-Band — 1100 mc to 3200 mc, and Model 802 covers X-Band — 7000 mc to 10,000 mc. It should be noted here that the frequency range can be extended to include any frequency range from 75 mc to 10 kmc by the use of additional PITLOG tuning units.

The apparatus affords direct reading of dynamic meter measurements of the long term and short term frequency stability of CW signals. Short term accuracy: 1 part in 10^9; long term accuracy: 1 part in 10^6. In addition, the short term stability disturbance waveform (FM) can be observed on an oscilloscope or spectrum analyzer. These stability measurements can be used to determine cancellation ratio and subclutter visibility limitations imposed by the stable frequency components on Moving Target Indicator radar systems.

CIRCLE READER SERVICE CARD 123

• • •

NEW ALFRED SWEEPING GENERATOR

A new microwave sweeping generator which provides either electronically swept or precise CW power from 2 to 4 kmc is now available from Alfred Electronics, Palo Alto, California, manufacturer of broad band microwave instruments and power supplies.

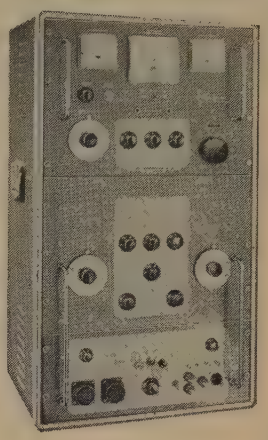
The Model 6002A combines time-tested Alfred instruments, including a backward wave oscillator, a 10-watt TW amplifier, a microwave leveler, and a high-voltage power supply.

Power output of Alfred's Model 6002A — adjustable from 10 mw to 1 watt — is held constant to within ½ db over the entire frequency band.

Operating controls permit selection of internal single or recurrent sweep, CW

(*Continued on page 67*)

IF YOU USE BWOs & TWTs



you need the NEW PRD 813

There is a "spanking" new BWO/TWT power supply that's really a work horse. PRD's latest contribution to the test equipment art, the Type 813 can supply just the right kind of power for driving a host of microwave tubes ranging from voltage-tuned magnetrons to travelling-wave amplifiers.

Featuring the latest advances, the PRD Type 813 has built-in time delays for filament and grid, delay line and collector, and anode voltages... and includes other frustration inhibitors, such as:

1. Individual adjustments of delay line, collector, anode, grid, and heater elements
2. Provisions for **both** internal and external sweep and amplitude modulation
3. AGC at the grid when used with external detectors
4. Digital read-out for delay line supply.

In addition to these features are the (typical of all PRD equipment) bedrock stability and high sensitivity of the first truly UNIVERSAL BWO/TWT Supply.

The remainder of the features and full specs for the PRD Type 813 can be yours by writing to: PRD—*first in microwaves.*

POLYTECHNIC RESEARCH & DEVELOPMENT CO., INC.

Factory & General Office:
202 Tillary St., Brooklyn 1, N. Y.
ULster 2-6800

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UPton 0-1940

CIRCLE READER SERVICE CARD 42

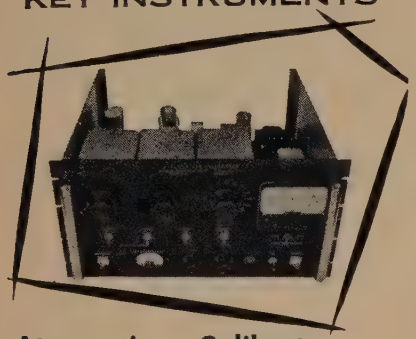
.01 db precision for 20 db measurement with changes of .1 db in level of r. f. source

WEINSCHEL

dual channel INSERTION LOSS TEST SET

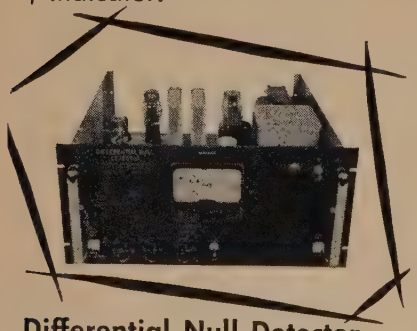
Systems Accuracy .02 db/10 db
20 db attenuation range, direct.
40 db range with partial r.f. substitution. Frequency Range:
20 MCS to 90,000 MCS

KEY INSTRUMENTS



Attenuation Calibrator, Model BA-5

Combines Precise Audio Substitution Attenuator, Bolometer Preamplifier and Level Indicator.



Differential Null Detector, Model ND-1

Specifically designed for two channel loss measurements.

For theory, method, required instruments and recommended accessories, request Application Notes #4.

Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12 KMC. Write for complete catalog, specifying frequency range of interest.

WE CO

Weinschel Engineering
KENSINGTON, MARYLAND

CIRCLE READER SERVICE CARD 43

DIRECTOR OF RESEARCH

Microwave Associates is currently expanding its research activities in the Microwave Device Field. As a result of a recent integration of all microwave tubes, duplexers, and switching devices into one operating division, a new research group is being formed to coordinate all research activities for the division.

To head this new group Microwave Associates is seeking a high calibre scientist who has distinguished himself in this field. A unique opportunity exists for professional and financial growth. Since this is a key position, the compensation will be most attractive.

A diverse research program is planned, initially involving such areas as:

New mechanisms for microwave power generation and amplification, particularly as directed towards millimeter frequencies.

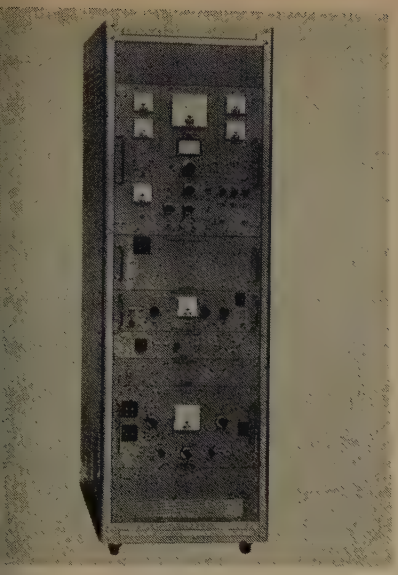
Microwave plasma physics.

Microwave interaction phenomena with plasmas and solid state media, such as ferrites and semiconductors.

Please phone collect or send resume to Dr. Lawrence Gould, Manager, Tube Division.

MICROWAVE ASSOCIATES, INC.

BURLINGTON, MASSACHUSETTS • BRowning 2-3000



eration, or external sweep. Frequency viation is independent of the starting quency, covering the entire range or part of it.

Single or recurrent sweep rates are table either for oscilloscope or recorder play. Relay contacts are included for gle sweep controls of the chart recorder. An internal 800 to 1200 cps square wave erator may be selected to amplitude dulate RF output. Power and high tage are controlled from a single wer panel.

The Model 6002A is designed to pro- both operator and microwave tubes. lix overcurrent and overvoltage relays n off high voltage when safe values are eeded. A similar sweeping generator available for 1 to 2 kmc operation.

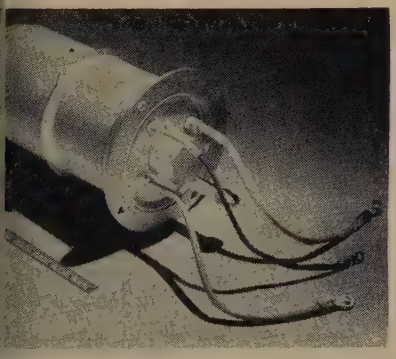
RCLE READER SERVICE CARD 124

• • •

NEW CERAMIC HYDROGEN THYRATRON BY G.E.

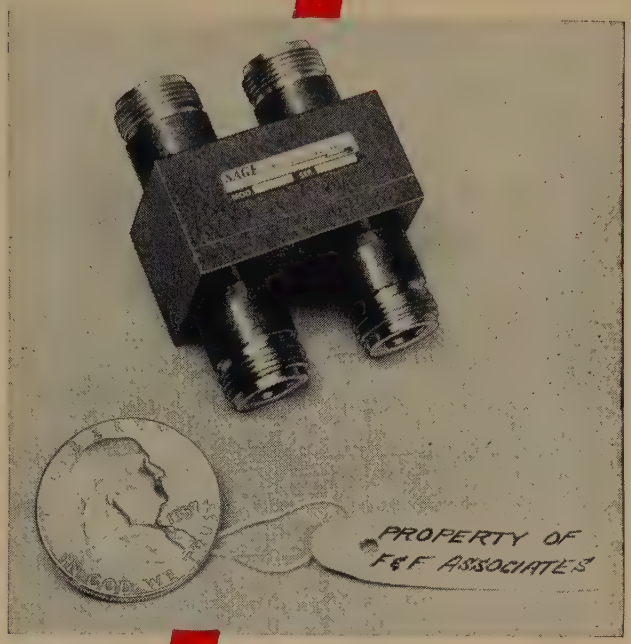
A new ceramic hydrogen thyratron de- ned for high-power radar pulse modu- rs which features increased power dling capabilities and smaller size has n announced by General Electric Com- y.

Developed by the Company's Power e Department, the new GL-7390 is



l to have the highest known power dling capability of any hydrogen thy- on now available, and is just 6 inches diameter by 12½ inches long.

maller size of the GL-7390 means im- tant space savings can be realized by ipment designers while attaining ater power handling capabilities. The



SAGE

Shown above* is the SAGE Model 753, one of a new series of miniaturized stripline hybrids. The units have a coupling of 3 ± .5 db and a directivity in excess of 20 db over the specified frequency range. VSWR is less than 1.30. The SAGE stripline hybrids are normally furnished with Type N conectors. Hybrids in all bands can be furnished with other types of connectors upon customer request. Delivery in small quantities is within 45 days after receipt of an order.

In addition to the small size, the SAGE stripline hybrids feature adjacent connectors for the two coupled outputs.

Model No.	*Frequency Range*	*(Dimensions Excluding Connectors) Width*	*Height*	*Length*	*Price*
749	125- 250 mc	7/8"	1 3/8"	11 3/4"	$225.00
750	250- 500 mc	7/8"	1 3/8"	5 3/4"	$225.00
751	500-1000 mc	7/8"	1 3/8"	3 1/2"	$225.00
752	1000-2000 mc	7/8"	1 3/8"	2 1/8"	$225.00
753	2000-4000 mc	7/8"	1 3/8"	1 5/8"	$225.00

*Our new quarters have prolonged the shortage of old half dollars. The Sage Half Dollar was furnished this month by our new New York City area representative.

CIRCLE READER SERVICE CARD 44

SAGE laboratories, inc.
3 HURON DRIVE NATICK, MASS.

DO *YOU* HAVE A SIZE PROBLEM?

CASCADE RESEARCH has designed and manufactures a series of new Y, T and Cross-type circulators— *one-tenth to one-fifth the size* of conventional types. Especially suited for maser and parametric amplifier applications where minimum size and weight are essential.

AVAILABLE IN THESE BANDS:
S - G - J - X L - X - K

GENERAL SPECIFICATIONS

Peak Power	100 K.W.
Average Power	100 watts
Maximum Insertion Loss	0.5 db
Minimum Isolation	20 db
Maximum V.S.W.R.	1.2
Frequency Band	5% or more

MONOGRAM PRECISION INDUSTRIES INC.

CASCADE RESEARCH DIVISION
5245 San Fernando Road-West / L. A. 39 / California / CHapman 5-8625

CIRCLE READER SERVICE CARD 45

tube has already been chosen for use in several prototype radar equipments now being developed.

The tube, immediately available from stock, incorporates design and manufacturing techniques conceived by General Electric designers to meet the specific needs of advanced high-power radar equipments.

Tube characteristics include: peak anode voltage (forward and inverse) of 33 kv, peak anode current of 2,000 amperes, average anode current of four amperes, and an anode dissipation factor of 30 x 109.

The GL-7390 is the first in a family of metal-ceramic hydrogen thyratrons being developed by General Electric for high-powered modulator applications. The Z-5101, similar in design to the GL-7390 but with higher voltage capabilities, will soon be available for prototype requirements.

CIRCLE READER SERVICE CARD 125

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INDUSTRY NEWS

500 KILOBIT PCM PULSES TRANSMITTED OVER TROPOSPHERIC SCATTER CIRCUIT

Five-hundred kilobit PCM pulses were transmitted successfully over a 93 mile tropospheric scatter path by the Communications Department, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J. A 12-voice channel pulse code modulation signal was transmitted from Tobyhanna Signal Depot, Tobyhanna, Pennsylvania to the Hexagon, Ft. Monmouth, N.J. This represents the first known transmission of high bit rate PCM information over distances greater than line sight. Previously the use of PCM multiplex equipment with microwave radio systems was limited to approximately 30 miles.

Fifteen-foot parabolic antennas were used at transmitting and receiving ends of the path with one kw of power transmitted. The circuit was operated on a one way basis, transmitting from Tobyhanna to Ft. Monmouth. The operating frequency was approximately 1830 mcs. The equipment used consisted completely of existing USASRDL material and required no new developments. These equipments were Signal Corps Radio Set AN/GRC-50 built by RCA, Camden, N.J., Signal Corps Multiplexer Set AN/-TCC-40 built by Raytheon, Waltham, Mass. and a microwave power amplifier built by ITTL, Nutley, N.J. Subjective talking tests made over the path indicate that voice transmission is not degraded by the randomly varying scatter signal above threshold. Diversity was not used for these tests indicating that further improvement can be achieved. Tests are currently being made to determine the percentage time on a hourly basis that the transmission is below the system threshold.

FOR AUTOMATIC NOISE FIGURE MEASUREMENT

Only THE NEW AIL TYPE 74 OFFERS THESE ADVANTAGES

- **Noise Figure Range, RF or IF**
  High Scale—23 to 36 db with extension to infinity
  Low Scale—0 to 25 db
- **Accuracy**
  Automatic:
  Low Scale—±1/2 db
  High Scale—±1 db
  Manual: ±0.1 db
- **Sensitivity**
  50 microvolts at 30 Mc;
  100 microvolts at 60 Mc
- **Bandwidth**
  6.0 .Mc minimum

All these features at a new, low price **$765.00**

Ten AIL Type 70 Noise Generators provide continuous coverage from 12 Mc to 40,000 Mc . . . most complete line of noise generators available for automatic noise figure measurements.

Write for details

AIRBORNE INSTRUMENTS LABORATORY
1345 NEW YORK AVENUE
HUNTINGTON STATION, L. I., N. Y.
A DIVISION OF CUTLER-HAMMER, INC.

CIRCLE READER SERVICE CARD

To the talented microwave engineer

COLLINS OFFERS GREATER FREEDOM OF ACTIVITY

Collins microwave research and development activities are expanding. As a result, staff members in Dallas, Texas participate in assignments of challenging scope. They range from basic research to installation of microwave components and systems.

A high degree of freedom of action enables Collins staff members to give free reign to their talents and ideas. Professional advancement and opportunities to accept program responsibility come rapidly. Promotion is rapid, too, because of the Collins policy of placing professional technical men at all levels of supervision.

A limited number of select openings exist for engineers qualified to accept unusual professional challenges. Salary is commensurate with experience and background. BSEE degree and experience in any of the following fields below is required.

Microwave Design
Design and development of microwave components and systems

Carrier Development
Development of carrier systems suitable for the transmission of voice data, teletype and facsimile

System Application
Microwave and carrier system or telephone transmission

Installation
Installation and maintenance of microwave and carrier systems

Collins also has a limited number of openings in the above categories for applicants who have recently received EE degrees, but do not meet the experience levels as outlined.

Engineers interested in these microwave project openings are requested to send their resumes in confidence to:
BEN E. JEFFRIES, Manager of Technical Employment,
Collins Radio Company,
1930 Hi-Line Drive, Dallas 7, Texas.

COLLINS

COLLINS RADIO COMPANY • DALLAS, TEXAS
CEDAR RAPIDS, IOWA • BURBANK, CALIFORNIA

engineers • scientists

DEVELOPING NEW APPLICATIONS FOR ELECTRONICALLY-SCANNED ANTENNA SYSTEMS

a broadening area of effort at Sylvania's Waltham Laboratories

The Waltham Laboratories is presently engaged in several systems programs whose immediate goal is to exploit the full potential of electronically scanned antennas. As a pioneer in this significant area, we are studying the feasibility of applying fixed antenna, steerable beam systems to missile detection radars, communications, satellite antennas, navigation and direction-finding systems. This technique has already provided measurable breakthroughs in several fields such as the complete integration of radar and digital data processing into a single programmable device.

The opportunity to apply your professional skills on vital, long-term projects is but one of many benefits at the Waltham Laboratories. Located in suburban Boston — electronics center of the world — great educational institutions, world famous scientists and active professional societies combine to create an atmosphere that increases personal creativity. Staff openings in these important areas are immediately available:

ADVANCED SYSTEMS ANALYSIS • ECM & GROUND SUPPORT EQUIPMENT • RADAR SYSTEMS DESIGN & ANALYSIS • RF CIRCUIT DESIGN & DEVELOPMENT • PLASMA PHYSICS • REAL-TIME DATA PROCESSING • SYSTEMS GUIDANCE & SIMULATION STUDIES • TRANSISTORIZED PULSE & DIGITAL CIRCUIT DESIGN • ELECTROMAGNETIC PROPAGATION • MICRO-ELECTRONICS • ELECTRONIC SYSTEMS TECHNIQUES • OPERATIONS RESEARCH & MATHEMATICAL ANALYSIS • MICROWAVE & ANTENNA ADVANCED DEVELOPMENT • ELECTRONIC & ELECTROMECHANICAL PACKAGING • PRODUCT ENGINEERING • RELIABILITY ENGINEERING • QUALITY CONTROL

Please send resume to Brooks Fenno, Dept. 9-J

Waltham Laboratories / **SYLVANIA ELECTRONIC SYSTEMS**

A Division of

SYLVANIA

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

100 First Avenue — Waltham 54, Massachusetts

INDUSTRY NEWS . . .

G. J. BROWN APPOINTED CHIEF ENGINEER OF DIAMOND ANTENNA AND MICROWAVE CORPORATION

Mr. Gerald J. Brown was recently a pointed Chief Engineer of Diamond A tenna and Microwave Corporation, Wa field, Massachusetts.

Prior to his appointment at Diamon Mr. Brown was Chief Electrical Engine of the Gabriel Electronics Division, T Gabriel Company; and previously serv with the Bell Aircraft Corporation.

Mr. Brown's experience includes ma years of antenna systems design. He h gained recognition for many of his co tributions to a variety of military a commercial programs such as the B Rascal Missile, White Alice and D Line Arctic early warning radar defe network, and the ASR-4 Airport S veillance Radar system. Mr. Brown h also worked on microwave relay antenn beacon antennas, counter measure s tems, and multiple channel rota couplers.

Mr. Brown graduated from Syracu University, with honors, and is a memb of Tau Beta Pi and Eta Kappa Nu hon societies.

• • •

FXR RECEIVES HALF MILLION DOLLAR CONTRAC

FXR, Inc. has received a half milli dollar contract through the approval of t award by Cornell Aeronautical Laborato Inc., of Buffalo, for the design and man facture of the most powerful radar tra mitter ever to be built, according to announcement from Henry Feldmann, FX president.

Previous work at Cornell Aeronauti Laboratory resulted in the transmission 21 million watts of peak power. Un CAL's accomplishment, the propagation microwaves into the air at such high pow was considered impossible without bre down of the electrical equipment. T Laboratory's new goal is a peak power some 50 million watts, with a variety pulse lengths and repetition rates. Also be sought are average powers up to thousand watts.

The desirability of acquiring informat that will enable the nation's radar design to build equipment to cope with such gets as ICBM's while they are still soar above the atmosphere and ionosphere, Army Ordnance to award a contract Cornell Aeronautical Laboratory for study and development of the necess techniques and components. Related pro gation phenomena, such as echos from ionosphere, cosmic dust, the aurora other atmosphere conditions are also to included in the study.

ughes-Fullerton can offer you a uniquely productive, gineering-oriented position...where you'll find unequalled om to expand professionally.

big promise. But let the facts speak:

eative Atmosphere—Engineers are encouraged to do dependent thinking. The many Hughes-Fullerton "break-roughs" are testimony to this creatively unhampered mosphere.

esearch and Development Orientation—Because e bulk of Hughes-Fullerton projects start from "scratch," gineers have the satisfaction of being in on vancements in the state-of-the-art. At the same time, ey can see that the final product fulfills program needs.

ng Range Projects—Hughes was first to develop ree dimensional radar. Today this work is expanding to compass highly advanced data processing systems d electronic display systems.

Privacy—At Hughes-Fullerton, engineers enjoy private or semi-private offices in new air conditioned quarters.

Growth of Opportunity—Hughes-Fullerton (30 minutes from downtown Los Angeles) has grown from 800 employees in 1957 to 5,000 today. This programmed growth means unusual advancement opportunity. Engineers' average age: 31. One out of five has an advanced degree.

It will pay you to investigate Hughes-Fullerton as the place to further develop your career as an engineer—no matter what your experience level. Please call or write to Mr. D. P. Ramstack, Director of Professional Placement, at the address below.

HUGHES

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FULLERTON-RESEARCH & DEVELOPMENT, FULLERTON, CALIFORNIA

ENGINEERS AND PHYSICISTS R & D ON NEW MICROWAVE DEVICES

Microwave Associates, Inc. invites qualified engineers and physicists to discuss an unusual opportunity to perform R & D work on new microwave devices utilizing ionized media, ferrites and semiconductors. A broad background can be achieved in the interaction of electromagnetic energy with non-linear lossy dielectrics. Here is an opportunity to grasp the advantages of each medium, combine their properties, and develop new devices.

Excellent high power and low power facilities are available for complete study and test of these devices over a wide frequency spectrum — 400 to 70,000 MC.

You are invited to a confidential exploratory discussion of your future with us. Contact Dr. Lawrence Gould for suitable arrangements.

MICROWAVE ASSOCIATES, INC.

BURLINGTON
MASSACHUSETTS
Telephone
BRowning 2-3000

Westinghouse *invites*

Senior Scientists and Engineers to explore opportunities in the NEW . . .

Microwave Research and Development LABORATORY

Accelerated growth in activity at the Electronic Tube Division in Elmira, N.Y. has recently required the establishment of a new Microwave Research and Development Laboratory. This has created several outstanding positions for experienced engineers and scientists. A rewarding future will be assured for men who wish to pioneer in uncharted areas of the microwave field. Those meeting the qualifications will find challenging assignments in association with the high caliber scientists and engineers at Westinghouse. Academic association with Cornell University is encouraged.

Write or send resume to:

Mr. William Kacala
Technical Recruiting
P.O. Box 284, Dept. M-D7
Elmira, N.Y.
or call collect Elmira REgent 9-3611

Westinghouse
ELECTRONIC TUBE DIVISION ELMIRA, NEW YORK

MICROWAVE ENGINEERS

PUT YOUR ORIGINAL IDEAS TO WORK IN A RAPIDLY GROWING RESEARCH GROUP

CURRENT INVESTIGATIONS INCLUDE:

- **Steerable Antennas**
- **Millimeter Wave Optics**
- **Solid State Electronics**
- **Ferrite Devices for use at Meter and Millimeter Wave Lengths**

NEW BUILDING WITH SPACIOUS OFFICES AND LABORATORY AREA CONVENIENTLY LOCATED IN NORTH BALTIMORE SUBURBS.

For further information, contact (Miss) A. M. Reeder, VAlley 5-5130

ELECTRONIC COMMUNICATIONS INC.

RESEARCH DIVISION

1830 York Road • Timonium, Maryland

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OPPORTUNITIES IN UHF AND MICROWAVE RESEARCH AND DEVELOPMENT

Never before has such high priority been given to microwave research and development . . . never before have the opportunities been so great in this field for the qualified engineer and scientist.

The Research Center of the Bendix Aviation Corporation—The RESEARCH LABORATORIES DIVISION—is expanding its programs in the UHF and microwave field to create interesting and challenging positions for qualified personnel.

Technical openings are now available in the following fields:

ANTENNA RESEARCH in electronic scanning, log periodic antennas, microwave optics.

MICROWAVE ENGINEERING—in ferrite devices, electronically controlled phase shifters, parametric amplifiers.

ELECTRON TUBE research in BWO and TWT from 1,000 to 150,000 mcs.

Investigate these opportunities *now*, where your technical competence and potentialities will receive full recognition in "Building Your Future with Bendix".

If interested, please write or wire Fred A. Barry, Research Laboratories Division, Bendix Aviation Corporation, P.O. Box 5115, Detroit 35, Michigan.

Research Laboratories Division
SOUTHFIELD, MICHIGAN

Bendix AVIATION CORPORATION

Engineers and Physicists:

radar
microwave
antennas
radio
communications

GPL announces junior, senior and intermediate openings in the design and development of circuitry, systems or components, for the latest in airborne missile guidance and Doppler techniques, as well as radio communications. Several of these positions require supervisory potential and carry commensurate salaries.

EE or Physics degree is desired plus some experience with either circuit design and analysis, or antenna and other microwave component design.

Engineers and Physicists who wish to arrange for a personal discussion of their future at GPL should call (collect) ROgers 9-5000, write or submit their resumes. Inquiries will be held in strictest confidence and answered promptly.

William U. Schell
GENERAL PRECISION LABORATORY INCORPORATED
63 Bedford Road, Pleasantville, N. Y.
(Situated on 69 wooded acres just north of White Plains)

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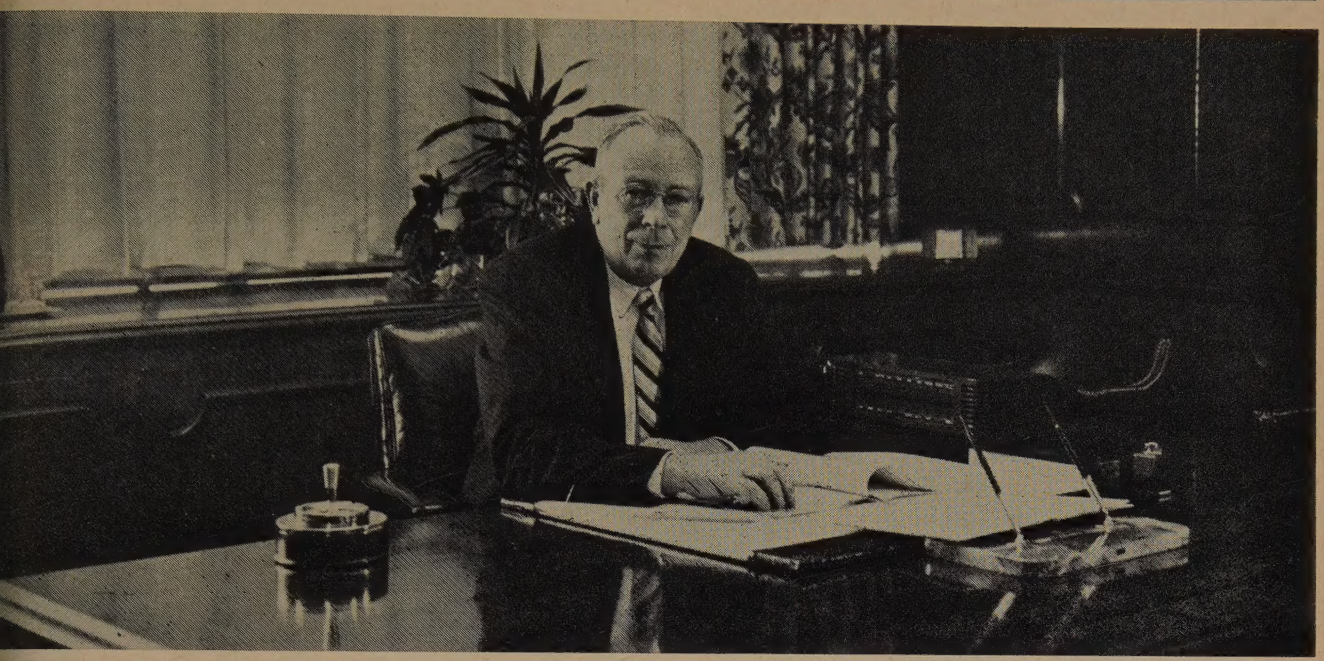

AWRENCE A. HYLAND is Vice President and General Manager of the Hughes Aircraft Company. In the five years he as been with Hughes, the Company has tripled in size and now pursues a flourishing electronics business with annual les exceeding half a billion dollars.

Ir. Hyland has had a long and successful career in electronics as an Engineer in the Naval Research Laboratory, as Vice resident of the Radio Research Company, in several high level positions in the Bendix Aviation Corporation, including ose of Vice President — Research and Vice President — Engineering, and now as General Manager of the Hughes Air- aft Company.

le is a Consultant to the Director of Research and Engineering of the Department of Defense, a Fellow of the Institute of adio Engineers, and a Member of the American Nuclear Society and the Scientific Research Society of America. The .S. Navy has awarded him a medal for distinguished public service, and he is the recipient of the 1957 Pioneer Award om the Professional Group on Airborne and Navigational Electronics of the Institute of Radio Engineers. In 1954, he as awarded the honorary degree of Doctor of Engineering by the Lawrence Institute of Technology.

MICROWAVE BREAKTHROUGHS IN THE SPACE AGE

By LAWRENCE A. HYLAND
VICE-PRESIDENT AND GENERAL MANAGER
HUGHES AIRCRAFT COMPANY

THE coming of the space age, with its tremendous speeds and distances, has brought with it many rmidable electronics problems. Only a few years ago, ese problems would have seemed completely beyond chnical solution because orders of magnitude of improve- ent would have been required.

Fortunately, our electronics scientists have not been idle - in fact, they have been making breakthrough after eakthrough. These have not been routine evolutionary nprovements — they have been step-function changes of eat significance.

asers

A breakthrough of major proportions has been made in e field best described as quantum electronics. This is ly revolutionary in that it is not merely an extension of the art, but a whole new approach to electronics, and involves a field of activity rather than a single device. Instead of free electrons, the electrons are used bound to atoms, molecules or crystal lattices. Binding bestows wonderful new properties — namely, that the discrete energy levels of quantum physics appear, with the ability to make transitions between such levels. Such transitions can be absorptive or emissive and are equivalent to the resonance vibrations of a classical oscillator. Accordingly, resistance, reactance and power generation can be obtained by what may be termed atomic circuit components. Energy can be stored in the levels or stationary states and recalled at will in the form of microwave radiation. Such recall is produced by stimulated emission in which the entire atomic system radiates coherently, so that very coherent oscillations or extremely low-noise amplification of the stimulat-

ing signal are obtained. Since there are no free electrons carrying current, there is no shot noise.

The maser typifies a component using quantum electronics. Two types are current — those using beams of molecules and those using crystalline solids for storing the r.f. energy.

The ammonia beam maser radiates the most coherent radiation known and oscillates with a stability equivalent to a deviation of only one second in 300 years. One of many uses for such a device is that of checking the general theory of relativity by flying a maser clock in a satellite and checking it against a similar clock on the ground.

A solid state maser uses a ruby to provide the energy levels. An equivalent noise temperature of only a few degrees absolute is reached in a solid state maser amplifier when cooled with liquid helium. Such amplifiers will provide tremendous increases in capability in such fields as radar, space communication, and radio astronomy.

Electronically Scanned Radars

In the past it has been necessary to move a microwave antenna mechanically in order to point its beam in any desired direction. For small antennas this has not been an important problem. However, for large antennas on the masts of ships, the weight penalties of mechanical scanning are great, and for the huge ground-based antennas required for ballistic missile detection, mechanical scanning is impractical.

Here again, the microwave engineer has come through with a new technique of major importance. He has devised means of electronically scanning the beam of an antenna in two dimensions, over wide angular limits, and with low side lobe radiation.

An application of electronic scanning which could be of great importance is that of ballistic missile detection. The new techniques now make possible a gigantic antenna system consisting of thousands of separate radiating elements, each element being fed from a separate microwave transmitter. The resulting pencil beam could be scanned both horizontally and vertically by appropriately varying the amplitude and phase of the radiation from each antenna element. The enormous size of the antenna in combination with the power from the multitude of transmitters, would make possible the detection of approaching ballistic missile warheads at ranges greatly in excess of our present capability.

Diode Parametric Amplifiers

The diode parametric amplifier is one of the most exciting developments in the microwave field since the discovery of the useful microwave properties of ferrites. Such amplifiers have a number of distinct advantages over conventional microwave amplifiers. The most important advantage arises from the fact that, unlike conventional hot cathode devices, the solid state amplifier produces no shot noise, and very little noise from thermal agitation. The improvement in noise figure over the best superheterodyne type receivers available today makes possible startling increases in the performance of our radar and communication systems. For example, the introduction of parametric amplifiers in certain of our present day radar systems will provide range increases equivalent to increasing the power output of the radar transmitter by a factor of 10 to 15 times.

There is little doubt that the diode parametric amp fier will play an increasingly important role in future crowave systems and will also be seriously considered retrofit in many of the existing radar and communicat systems. The simplicity of the microwave circuitry volved makes the diode amplifier a relatively inexpens rugged, and reliable component for airborne, shipboard, ground-based radar systems. It should also prove parti larly valuable in applications such as UHF and L-band Sc ter Propagation systems, in Air Route Traffic Control Airport Surveillance Radars, and in satellite communi tion systems.

High Power Traveling Wave Tubes

Since World War II, bomber and interceptor aircr speeds have increased by factors of 2 to 3. In additi missiles of high Mach number have come into their ov As a consequence, the requirement for radar range increased by a factor of four or more.

Such increased ranges are not easily attained. A 16 t increase in radar average power is required for only a fac of 2 increase in range (or 256 for 4 times the range). addition, the ground clutter, which tends to obscure target being sought, becomes hundreds of times more di cult. To top it off, electronic countermeasures by a tential enemy have developed to a point where evas tactics on the part of the radar are essential for dependa performance.

Since the power output from radar tubes was already levels which had required enormous scientific and dev opmental effort during the war period and for ten ye afterward prior to these new requirements, it might app that improvements of the magnitude described might considered virtually impossible.

Yet during the past few years, all three of the desi objectives, increased range by a factor 4, necessary red tion of clutter, and evasion of countermeasures have b simultaneously accomplished. In addition to the use doppler techniques and clever information processing major breakthrough in radar tube performance was nec sary. The device which accomplished this is known as high power traveling wave tube.

Traveling wave tubes of a few years ago had been p fected only to a level of a few watts of average power were bulky, unwieldy and delicate. In addition, they heavy power consuming electromagnets. Through a c centrated effort by many scientists and engineers who sol problems in electron flow comparable to going from s sonic aircraft to super-sonic aircraft, problems in elec magnetic interaction of a nonlinear nature soluble c through the use of the largest electronic computing chines, and problems in heating and focusing solved c by the development of new materials not in existence the beginning of the program, the solutions were fou Average power output was increased from one one-h dredth of ordinary radar tubes to one hundred times dinary radar tubes. At the same time, size, weight, rugg ness and the absence of power consuming solenoids w all made to fit necessary requirements.

Through many difficult and generally unheralded sc tific and engineering individual and team accomplishme breakthroughs such as those just described are being m to satisfy the needs of American security and the futur

SHAGGY FISH STORY

At the height of the Boston Tea Party, while the "Indians" were busy throwing everything in sight over the side, the British radar operator suddenly found himself pitched overboard.

Since he couldn't swim, he clung precariously to a wooden tea case bobbing in the water, and floated aimlessly around, thrashing wildly and yelling for help.

Just as he was about to lose his grip on his precious raft, a codfish surfaced nearby.

"What's going on here?" the codfish asked.

"Some wild Indians surprised our radar, overran the ship, and threw all the tea overboard," the radar man gasped.

"Well," the codfish said, "Bet you a fin you didn't have any Bomac tubes in that radar of yours."*

"Good cod, here I am drowning in front of your eyes and you have to give me a commercial," the man said. "I can't hang on much longer!"

The fish ignored him. " . . . Anybody knows Bomac makes the finest microwave tubes and components either side of Boston Harbor," he said.

"Look," the man said. "I've just about haddock. But tell me this: How do you know so much about microwaves?"

"I'm no expert," the codfish said. "I just dabble in it for the halibut."

"O," the man said. And he sank silently into the sea.

No. 16 of a series . . . **BOMAC LOOKS AT RADAR THROUGH THE AGES**

**Bomac makes the finest microwave tubes and components either side of Boston Harbor*

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lers in the design, development and manufacture of TR, ATR, Pre-TR tubes; shutters; rence cavities; crystal protectors; silicon diodes; magnetrons; klystrons; duplexers; surizing windows; noise source tubes; high frequency triode oscillators; surge protectors.

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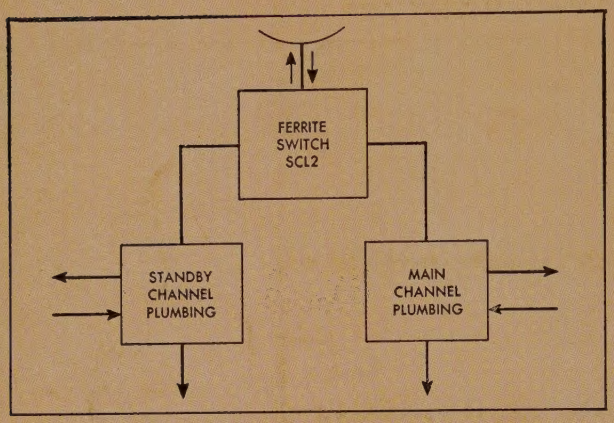
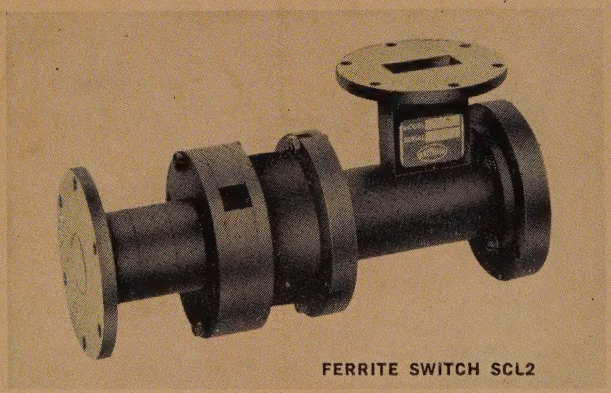
THREE-POSITION FERRITE SWITCH FOR C-BAND



TYPICAL MICROWAVE CIRCUIT in which Raytheon ferrite switch is now being used. Switch has three positions: antenna to main channel; antenna to standby channel; antenna to both channels simultaneously.



FERRITE SWITCH SCL2

FERRITE SWITCH IS ACTIVATED when fault is detected in sensing unit. Receiver fault causes switch to transfer to intermediate position for comparison of main and standby. Normal baseband receiver noise and pilot tone allow switch to complete switchover.

ADVANCED SWITCHOVER PROTECTION PERMITS MORE RAPI AND FLEXIBLE OPERATION THAN EVER BEFORE

A completely new ferrite switch has just been intr duced by Raytheon. The device, which is controll by a specially designed switchover unit, provides foo proof switchover protection. It has three position connecting:

1. antenna to main channel
2. antenna to standby channel
3. antenna to both channels simultaneously

In the third position, the received signal is divid equally between the arms feeding the main and stand receivers.

This allows an actual comparison of the two receiv signals before switching and eliminates the need f complex and unreliable signal injection systems.

To learn more about this significant development other important Raytheon advances in microwave fe rite devices, please write to the address below stati your particular area of interest.

RAYTHEON COMPANY
SPECIAL MICROWAVE DEVICES
WALTHAM 54, MASSACHUSETTS

RAYTHEON *Excellence in Electronics*

TYPICAL SPECIFICATIONS

	SCL2
Frequency range (mc)	*6,575-6,875*
Isolation, minimum	*20db*
Isolation, maximum	*30db*
Insertion loss, minimum	*0.5db*
Insertion loss, maximum	*0.8db*
Power, average	*10 watts*
Power, peak	*1 kw*
VSWR, minimum	*1.02*
VSWR, maximum	*1.28*
Type of switch	*SPDT reciprocal*
Coil current	*400 ma*
Coil resistance	*60 ohms*
Length	*8 in.*
Waveguide	*RG-50/U**

*Mates with